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STEM Program for the Boys & Girls Club of Worcester

Alexandra Leigh Bittle
Worcester Polytechnic Institute

Lindsay Hanna Braith
Worcester Polytechnic Institute

Lubna Ali Hassan
Worcester Polytechnic Institute

Michael W. Sullivan
Worcester Polytechnic Institute

STEM Program for the Boys & Girls Club of Worcester

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By:
Alexandra Bittle
Lindsay Braith
Lubna Hassan
Michael Sullivan

Worcester Community Project Center
Worcester, Massachusetts, United States

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Report Submitted to:

Project Sponsor
Ms. Joanne Fowling
Mr. Tomas Aponte
Boys & Girls Club of Worcester

WPI Faculty Advisors
Professor Corey Dehner
Professor Melissa Belz
Worcester Polytechnic Institute

ABSTRACT

In response to a growing national concern about the dearth of STEM (Science, Technology, Engineering, and Math) professionals, the Boys & Girls Club of Worcester, MA have asked us to collaborate in developing an implementable STEM education program. The curriculum, tailored to 10-13 year old youth, aims at fostering interest, understanding, and appreciation of the STEM disciplines. The program provides early exposure and increased appreciation towards the STEM fields through hands-on engagement.

ACKNOWLEDGMENTS

We acknowledge that this project would not have had sufficient completion without the tremendous support and assistance we received from individuals along the way. We give immense gratitude to our project advisors, Professors Corey Dehner and Melissa Belz, who’s advice and guidance added to the successful progress of our project. Additionally, we give our sincere gratitude to our sponsors at the Boys & Girls Club of Worcester, Joanne Fowling and Tomas Aponte, whose generous efforts to provide a beneficial program for their members was seen in their motivation, patience, and enthusiasm for our project.

There are numerous other individuals we would like to extend our gratitude towards for their contributions in the culmination of our work. Listed alphabetically below are the professionals responsible for the extending their knowledge towards our creation of the program’s STEM curriculum.

The Boys & Girls Club of Worcester

- Tomas Aponte – Education Director
- Joanne Fowling – Volunteer Coordinator
- Elizabeth Hamilton – Executive Director
- All the kids at the Boys & Girls Club of Worcester who welcomed us and showed enthusiasm through the focus groups and pilot sessions

Worcester Polytechnic Institute

- Martha Cyr – Executive Director of the WPI STEM Education Center
- Sherri Weaver – K-12 STEM Education Outreach Staff
- Worcester Project Center Students who participated generously in our piloted activities

Local STEM Professionals

- Dr. Deborah Harmon Hines- Vice Provost of School Services

- Mr. Robert Layne- Director of Outreach Programs and Worcester Pipeline Collaborative
- Lauren Monroe – Co Director of Worcester's Think Tank
- Elisa Heinricher – Computer Science teacher and VEX Robotics coach at Bancroft School (Worcester, MA)
- Donata Martin – Executive Director at Boys & Girls Club of Fitchburg and Leominster (BGCFL)
- Tricia Desmarais – Director of Local Camp Invention in Millbury

EXECUTIVE SUMMARY

Introduction

The need for STEM (science, technology, engineering, and math) professionals is growing in today's society, but interest in these fields is dwindling. In response, many organizations have developed STEM education programs. These programs are geared toward children, so that lessons can provide and help build an early interest in STEM fields. In central Massachusetts, the Boys & Girls Club of Worcester (BGCW) provides extensive services to their members, which promote academic enhancement and personal growth. The Club has seen increased member interest in piloted STEM educational programs. As a result, the BGCW asked the WPI-WCPC to create a program that would foster STEM interest and increase understanding. The purpose of our project was to develop and prototype an engaging educational program, which would allow the Boys & Girls Club of Worcester to effectively and consistently introduce its 10-13 year old members to STEM. Ultimately, the program will get the kids excited about STEM through interactive learning objectives and fun activities that apply to real-world scenarios.

Background

In the 21st century, the American economy revolves around modern technology and the services that innovations have provided for the American public that complement our everyday lives (e.g. cell phones). Science, technology, engineering, and mathematics – commonly known by the acronym STEM – are the disciplines that deal with the theories and application of the scientific method and mathematical concepts. These disciplines fuel innovations in the U.S. economy. However, despite a projected job growth in the STEM sector of 13 percent by the year 2022, less than 20 percent of American students are entering STEM related majors in higher education. Based on declining numbers of students in STEM fields, the U.S. Government considers STEM an “area of national need” (Kanny et al., 2014).

In response to current national trends, STEM educators have created a movement with the solution of increasing the number of people pursuing STEM careers is early STEM education, especially in communities with underserved youth. In America, women and minorities are vastly underrepresented, as STEM professionals have remained predominantly white and male (Grossman & Porche, 2013). By understanding the obstacles faced by underrepresented populations in STEM, academic institutions and other segments of society can work to change the trickle-down discrimination faced by children in those populations.

Restrictions (e.g. financial, admission numbers, resources, etc.) in publicly funded educational programs have limited the capability for growth beyond the classroom in children primarily raised in low-income, urban settings. There are few extracurricular programs/activities that are available to these students which may supplement the information being taught in their classrooms (Kanny et al., 2014). Nationwide, many institutions have integrated STEM courses into their curriculums in order to bridge the gap of under representation as well as increase the number of college students entering STEM professions, which remains lower than 20 percent (Synder & Dillow, 2013). By providing services that promote and engage all learning styles, instructors can expose students to STEM in a multi-faceted way. Local STEM professionals have expressed that without accommodations made in the learning environment and learning structure, children will not reap all of the possible educational benefits that may bolster their learning experience. Furthermore, without early exposure to the STEM disciplines, the national trend of underrepresentation and the gap present in college graduates entering the fields will ensue.

In recognizing the importance of early STEM education, the Boys & Girls Club of Worcester (BGCW) sought to collaborate with the Worcester Polytechnic Institute's Worcester Community Project Center to establish a STEM core curriculum. As a nonprofit organization in Worcester, Massachusetts, the BGCW upholds a mission to promote educational achievement and contributes its own ideals to the community (Foundation for the Future, 2013). The goal of our project was to develop and implement a hands-on STEM education program (mirrored with MA Common Core Standards) at the BGCW. The purpose is to provide their middle school members (age 10 to 13) with engaging activities to increase their appreciation towards STEM, and broaden their understanding of their abilities to attain such opportunities.

Methodology

We created a list of objectives to achieve our goal of creating a 7-week STEM education program for the students of the BGCW. First, we conducted a meta-analysis of existing STEM enrichment programs working with 10-13 year old students. After holding small focus groups with the children at the BGCW, we identified preconceptions about STEM and the level of interest in STEM amongst these children. We determined appropriate and feasible learning outcomes for the program after consulting online sources, and interviewing several local STEM educators.

Using the learning outcomes that we developed, we created an implementable STEM curriculum that would ensure the program participants would achieve these learning outcomes. We based the curriculum on responses from focus groups and online sources recommended by the STEM advocates and educators we interviewed. Preceding the creation of the curriculum, we selected a few activities to pilot with the children at the BGCW. As a means of evaluating the pilot sessions, we administered pre- and post-evaluations in the first and last sessions. Based on these evaluations, we modified and improved the program curriculum to prepare for its launch in the spring of 2016.

Findings

Background research, focus group discussions, interviews, and pilot sessions, allowed us to distinguish specific findings. Our findings, although numerous, fell into categories, which addressed larger, more complex topics. The findings were categorized by: Best Practices for STEM Integration in Urban Youth and Perceptions of and Level of Interest in STEM. Through our research, we discovered that some educational approaches are better at inspiring children's interest in STEM. We compared the approach and results of suburban youth STEM enrichment programs, such as Camp Invention and other tuition-based programs against STEM programs at the Boys & Girls Club of Fitchburg and Leominster and the Worcester Think Tank, to identify the most effective curriculum for the children at the BGCW. We found that children learn best through hands-on activities, the process of tinkering, after interviewing Camp Invention instructors (T. Desmarais, personal communication, November 2, 2015). However, the concept is that urban youth will thrive exponentially in an experiential learning environment as they are able to gain responsibility and ownership over their learning process. Dr. Deborah Harmon Hines, the Vice Provost of School Services at the University of Massachusetts Medical School, supported this claim by expressing that urban youth students flourish in hands-on learning environments due to individual responsibility they are given matched with the confidence they receive performing worth-while activities. This was bolstered with further findings supporting the relation to real-world, problem-based learning, and the understanding that economic and cultural backgrounds do not hinder the academic progress or ability among urban youth.

Further supported through field interviews and focus groups with BGCW youth, we found that at the BGCW, cultural and economic backgrounds influence the interest among 10-13 year olds in the STEM disciplines. Through conversation with our sponsor, it was clear that students at the BGCW come from varying cultural backgrounds, and the influences placed upon them from their parents, religion, or cultural beliefs is very realistic (J. Fowling, personal communication, November 26, 2015). These influences may dictate not only the interest level of the student regarding STEM, but also children's ability to foresee themselves in specific STEM careers (if hindered by or under pressure of parental opinion). However, through focus group discussion and observations within the Club, we found that interest in STEM is still expressed among BGCW members. To foster such interest within a classroom or program, we found that students perceive lessons in a nature that is reflective of the teaching style and learning environment. This means that through further understanding of possible obstacles children may face, classroom environments and instructors may foster varying learning styles and levels of interest.

Based on our findings, we established four learning outcomes that we used to develop the curriculum. The learning outcomes can be found in Table i. The outcomes outline the goal of the program, and represent the optimistic future and attainable opportunities for each program member. By providing lesson plans focused in experiential learning, but grounded in Common Core Standards, students will actively engage in educational lessons that broaden their understanding of the STEM professions and increase positive attitudes towards STEM.

Recommendations

Through the collection and organization of our findings, we uncovered six recommendations to provide further sustainability of the program. First, we recommend all future STEM program lessons at the BGCW provide a hands-on, experiential, problem-based learning experience. This will bolster the depth with which urban youth are able to engage with the STEM professions. Furthermore, we recommend that STEM programs, like this one, -be evaluated to assess student improvement and program success. This evaluation can come from student self-report or discussion that lay out strength and weakness, which provide foundation for establishing the success of the program. Consecutively, we recommend that the pre- and post- evaluations, supported by objectives laid out for each individual lesson, should be administered at the beginning and end of the program to assess student and program improvement. By providing pre- and post- evaluation discussions, instructors will be able to assess how well the lesson was received/understood based on student response. We further recommend that the students be segregated based on gender to ensure that underrepresented girls have a supportive environment, but that curriculum remain the same for both sexes to secure equality and similarity among content within the lessons. To ensure continuity and familiarity within the classroom, we recommend the BGCW have program alumni return as mentors to provide volunteer services to their other students. We felt as though this recommendation would be easily fulfilled as BGCW members remain in the organization until the age of 18, and older children are encouraged to take a leadership or mentoring role. By allowing students to return and mentor, younger program members will not only have consistent/familiar role models, but also a peer mentor that can provide additional understanding to the STEM topics.

Finally, to confirm that the students are receiving increased exposure to the STEM fields and professionals, we recommend, if funding permits, that the program provide field trips to STEM related locations such as Maker's Spaces, or consider guest speakers/groups to facilitate certain activities during a session. We recognize relevant recommendations for out-of-school

STEM programs, and also offer suggestions that may act as viable opportunities in program improvement and ways to provide for a more sustainable program.

Deliverables

We developed a 7-week core curriculum to be implemented by instructors of the STEM program at the BGCW in the Spring of 2016. Table i contains a synthesis and summarization of the components of the program's curriculum.

<table>
<tr><th colspan="2">Program Layout</th></tr>
<tr><td>Goal:</td><td>To develop and implement a hands-on STEM education program that focuses on increasing student appreciation and positive attitudes towards STEM, and promote an understanding of the depth of STEM fields.</td></tr>
<tr><td>Duration of Program:</td><td>7-Week Curriculum
Bolstered by smaller backup units (Permits flexibility)</td></tr>
<tr><td>Target Audience:</td><td>The curriculum mirrors Common Core and Next Generation Science Standards relative to middle school aged students.
5th through 8th grade students (ages 10 to 13)</td></tr>
<tr><td>Deliverables:</td><td>• Instructor's manual which includes a detailed curriculum lesson plan and any necessary teacher/student review sheets
• Resources for exposure: field trip possibilities, communities connections, and unique STEM portfolios</td></tr>
<tr><td>Learning Outcomes:</td><td>1. Increase engagement, interest, and positive attitudes towards STEM
2. Children are able to apply STEM principles through hands-on learning (outside of the classroom)
3. Children develop a greater understanding of the breadth of STEM fields and their abilities to attain such opportunities
4. Students reinforce concepts set by the Massachusetts Common Core and Next Gen. Science Standards</td></tr>
<tr><td>Structure of Sessions:</td><td>Each hybrid lesson consists of one or more ways to associate discussion with varying STEM professions. Students participate in lessons involving both group and individual work. Upon completion of the program students will have participated in activities involving one or more of the STEM disciplines.
• Introduction discussion
• Hands-on activity
• Closing discussion</td></tr>
<tr><td>Activities Involved:</td><td>• Hands-on, experiential learning activities
• Student reflection through worksheets
• Analysis/discussion of findings
• Take home assignments or further research</td></tr>
</table>

Table i: Layout of the curriculum and its involved components

Conclusion

With this project, we believe the program can inspire urban youth in Worcester to pursue careers in science, technology, engineering, and math in the future. Children at the BGCW will learn not only the benefits of a STEM career, but also that STEM is an exciting and potentially very rewarding field.

AUTHORSHIP

Chapter/Section	Primary Author(s)	Primary Editor(s)
Table of Contents	Drafted by Michael Sullivan	Edited by All
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2.2 STEM Education	Alexandra Bittle	Lindsay Braith
2.3 How Do Kids Learn?	Lubna Hassan	Alexandra Bittle
2.4 Need for STEM in Worcester	Lindsay Braith	Michael Sullivan
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3.4 Objective 4	Lubna Hassan	Alexandra Bittle
3.5 Objective 5	Michael Sullivan	Lubna Hassan
3.6 Objective 6	Lubna Hassan	Alexandra Bittle
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Chapter 1: INTRODUCTION

In many urban settings, children often suffer the most, largely due to socioeconomic adversity from financial stress, as well as academic adversity due to low quality education (Peske & Haycock, 2006). Restrictions in publicly funded enrichment programs have become a nationwide issue that has limited the capability for growth beyond the classroom in children primarily raised in low-income, urban settings (Kanny et al., 2014). Children in low-income, urban settings face subpar support resources as well as consistent obstacles hindering the development of their self-identity, or one's potential and qualities as an individual (Wilson et al., 2015).

The need for STEM (Science, Technology, Engineering, and Mathematics) professionals is growing in today's society, but interest in these fields is dwindling. By the time students reach college, fewer than 20 percent of them enroll in STEM-related majors (Snyder & Dillow, 2013). However, for those students who overcome the adversities and enter the competitive fields of STEM, the benefits are immense. STEM fields have a projected growth of 13 percent by the year 2022 and offer consistently higher salaries than non-STEM jobs (Vilorio, 2014; Langdon et al., 2011). Those who have access to supplemental education programs and extracurricular STEM lesson plans are more likely to possess the tools to compete in such challenging disciplines. Therefore, introducing math and science to students at a young age will help address the national need for STEM professionals by increasing the number of students interested and qualified to pursue STEM careers.

In attempts to counter the impact of low-quality education or limited resources in the public school system, many after school programs and organizations have integrated science, technology, engineering, and math (STEM) courses into their curriculums (Leos-Urbel, 2013).

The Boys & Girls Clubs of America is a nonprofit organization that makes youth enrichment its responsibility through promotion of academic and personal growth. Its mission is "to enable all young people, especially those who need [it] most, to reach their full potential as productive, caring, responsible citizens" (Boys & Girls Clubs of America, 2015). One way the Boys & Girls Club fulfills its mission is through its emphasis on education. In 2014, 73 percent of low-income Club members applied for post-secondary education (2014 Outcomes Report, 2014). This means Club members sought higher education courses beyond high school graduation in either collegiate or post-secondary certificate programs. In comparison, only 51 percent of students at low-income, high-minority urban schools throughout the nation applied to post-secondary schools (National College Progression Rates, 2014). The Boys & Girls Club hopes that these numbers will increase as more young people immerse themselves in its programs.

In central Massachusetts, the Boys & Girls Club of Worcester strives to provide services which promote academic development and advancement. Club members have access to educational programs such as individual tutoring and homework guidance. Additionally, in the spring of 2015, the Boys & Girls Club of Worcester (BGCW) piloted a STEM education program and saw potential for a successful yearly STEM program. As a result, the purpose of this Interactive Qualifying Project was to develop and prototype an engaging educational program, which will allow the Boys & Girls Club of Worcester to effectively and consistently introduce its 10-13 year old members to STEM. Ultimately, the program will get the kids excited about STEM through interactive learning objectives and fun activities that apply to real life scenarios.

In this report, we introduced the detailed research and methods that helped us accomplish our goal. In Chapter 2, we discussed the background information that provided relevant context to our field of work by exploring the concept of STEM, the importance of STEM careers and integration, the preconceptions and stereotypes surrounding the field of STEM, as well as STEM's overall importance to children. Then, in Chapter 3, we described our objectives and the methods we used to develop a STEM curriculum. In Chapter 4, we explained our findings and recommendations, and in Chapter 5 we introduced our project deliverables- the STEM program curriculum-, explaining how the project findings led to a detailed program manual/curriculum. Finally, we conclude our report in Chapter 6.

Chapter 2: BACKGROUND

In this chapter, we discuss the relevance of science, technology, engineering, and mathematics (STEM) and its importance to the 21st century society. In section 2.1, we explore the current increase in STEM careers. In section 2.2, we discuss the importance of STEM education for children and STEM education efforts. Then, in section 2.3, we assess effective teaching methods and their potential applications to STEM education. Finally, in section 2.4, we describe the current efforts and hopes of our sponsor, the Boys & Girls Club of Worcester, to generate interest in STEM among the at-risk youth in Worcester.

2.1 The What, Why, and Who of STEM

STEM is a vast field that has become increasingly more important since society relies heavily on technological advancements. In this section, we introduce STEM, its importance, and the people involved in the ever-expanding fields.

2.1.1 What is STEM?

Science, technology, engineering, and mathematics – commonly known by the acronym STEM – are the overarching disciplines that lend themselves to “deep technical and personal skills” (Bybee, 2010). More than just math and science, STEM encompasses the set of skills that represent the “symbiotic relationship among the four interwoven fields” (Basham & Marino, 2013). The disciplines are interrelated as mathematics is heavily involved in physics, which gives way to the engineering that can result in technological advancements (Vilorio, 2014). The STEM skillset opens doors to an expansive field of careers and opportunities. Of course, traditional scientists and mathematicians require experience in STEM, but even teachers, financial professionals, and those involved in agriculture draw success from a background in

STEM (Vilorio, 2014). Since STEM touches so many professions, the question, "What is STEM?" prompts an answer that STEM is a doorway to many career opportunities.

2.1.2 Why is STEM Important?

Life in 21st century society is effectively dependent on innovative technology that eases the processes of daily tasks. As of October 2014, 64 percent of Americans owned a smartphone (Smith, 2015). However, with the majority of Americans owning smartphones, how many people understand the technology that goes into their devices? To help answer that question, STEM education professional Thomas Dubick gave a talk at a TEDx event, an independent conference promoting technology, entertainment, and design (Dubick, 2012). During his speech, Dubick asked audience members if they owned a smartphone; the theater filled with raised hands. However, most of the hands dropped when asked who understands the technology that goes into the smartphone. Through this interactive opening to his talk, Dubick effectively illustrated the knowledge gap among Americans that exists in fields relating to science and technology.

Since such technological innovation as the smartphone is central to 21st century daily life, the same innovation is now "central to the performance of [the] economy," and, according to former executive director of the Biological Sciences Curriculum Study Rodger Bybee, has been "for more than 50 years" (Bybee & Fuchs, 2006). As a result, a vast job market exists to meet the needs of constant innovation, and the number of careers in the STEM field is projected to grow 13 percent from 2012 to 2022 as compared to just 11 percent growth in all occupations as a whole (Vilorio, 2014). Additionally, STEM professions are among the highest-paying jobs. As Table 1 below displays, in 2010 STEM careers consistently offered higher salaries than non-STEM careers at all educational levels (Langdon, McKittrick, Beede, Khan, & Doms, 2011). Despite such positive outlooks regarding the STEM fields, potential STEM professionals do not fully understand the opportunities available in STEM fields.

	Average hourly earnings		Difference	
	STEM	Non-STEM	Dollars	Percent
High school diploma or less	$24.82	$15.55	$9.27	59.6%
Some college or associate degree	$26.63	$19.02	$7.61	40.0%
Bachelor's degree only	$35.81	$28.27	$7.54	26.7%
Graduate degree	$40.69	$36.22	$4.47	12.3%

Source: ESA calculations using Current Population Survey public-use microdata and estimates from the Employment Projections Program of the Bureau of Labor Statistics.

Table 1. "Average Earnings of Full-Time Private Wage and Salary Workers in STEM Occupations by Educational Attainment, 2010" (Langdon, McKitrick, Beede, Khan, & Doms, 2011)

The solution to increasing the understanding of these opportunities and increasing the number of people pursuing STEM careers, is early STEM education. Integrating educational and engaging STEM programs around the country is the key to preparing future generations for the growing job market of STEM careers and to maintaining America's competitiveness in the global market (Bybee & Fuchs, 2006). Though the number of college-age students enrolling in STEM degree programs is slowly rising, STEM degrees continue to make up fewer than 20 percent of undergraduate degrees in the United States (Snyder & Dillow, 2013). Consequently, America falls behind many countries in STEM education. International benchmarks indicate that science literacy among 15-year-old Americans ranks outside the top fifteen countries (National Science Board, 2007). Additionally, a historical view indicates that the scientific achievement benchmark among American students remained within a 10-point range since 1995, while top performing countries like Korea and Singapore have moved to be over 35 points ahead of the United States (Martin, Mullis, Foy, & Stanco, 2012). If the United States is to remain competitive in this knowledge-based economy, it must emphasize STEM education, thereby sufficiently preparing future generations for the changing professional landscape.

2.1.3 The Status of STEM in the United States

In the United States, the STEM fields have seen projected growth. However, based on declining numbers of students in STEM fields, the U.S. Government considers STEM an "area of national need" (Kanny et al., 2014). Gender and ethnic diversity are lacking in the STEM careers. As of 2010, "[w]hite males historically have dominated STEM fields, both in number and in perception as the normative picture" (Riegle-Crumb & King, 2010). Women and minorities remain underrepresented in STEM fields (Grossman & Porche, 2013). By understanding the obstacles that underrepresented populations in STEM face, academic institutions and other facets of society can work to change the trickle-down discrimination faced by children in those populations.

Women and STEM: Although STEM careers are quickly becoming a high-profiled field, there is still a dearth of gender diversity. Women represent only 24 percent of STEM professionals; of those women, half quit or find alternative career paths within the first ten years of entering the field (Beard 2014; MWM, 2015). As Figure 1 illustrates, men dominate STEM careers. While non-STEM jobs maintain a roughly even split of males and females, men comprise over three-quarters of the STEM workforce (Beede, Julian, Langdon, et al., 2011). Although data collected from the Million Women's Mentors Movement reports that women in STEM fields make almost as much as men at 92 cents to the dollar, only 13 percent of young American girls reported a desire to pursue STEM-related careers (MWM, 2015). Thus, gender diversity is likely to remain deficient in STEM occupations.

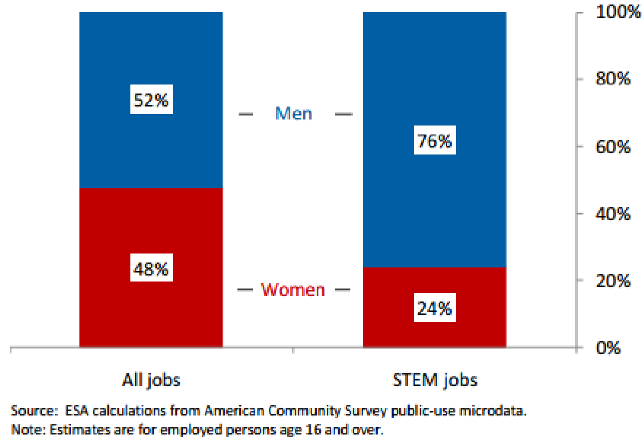

Figure 1. "Gender shares of total and STEM jobs, 2009" (Beede, Julian, Langdon, et al., 2011)

There are a number of reasons for this underrepresentation of women, including: (1) lack of female role models in STEM; (2) lack of early exposure to science; (3) masculine connotation of STEM fields and stereotypes imposed by others (external influence); and (4) young women's own perception (internal influence) that STEM does not work with family life.

An important approach to reversing this trend is greater representation of role models for young women in the STEM fields. Without the ability to connect with role models in the STEM fields or gain a sense of empowerment through mentoring experience, the younger generations of women will lack self-efficacy, the personal belief in one's ability to reach goals, be successful, and to have control over one's life path. Without first picturing herself as successful, a woman cannot keep up with the competitive nature of the STEM career field. For women of color, the underrepresentation is even more vast and likely points to a lack of a deeper understanding of the individual's background and personal obstacles/challenges (Syed and Chemers, 2011). For all, STEM careers are not only intellectually demanding but also the highly competitive nature requires high degree self-confidence, which directly relates to self-efficacy (Wilson et al., 2015). In male-dominant career fields, it becomes even more difficult to identify strong female role models leaving the younger generation to feel the subsequent effects.

Lack of early, meaningful exposure to science and math feeds this trend. Researchers analyzed gender typicality (masculine/feminine connotation) and aptitude perception surrounding STEM fields to explore the reasons behind this underrepresentation. In a 2000 study performed by Interim Dean of Education and Human Development at the University of Delaware, Nancy Brickhouse, to assess the connection between a child's personal identity and 'her' academic identity, researchers concluded the exclusion of women from science fields is a direct result of impeding academic opportunity during early education (Brickhouse et al., 2000). Students' personal identities matched their academic identities; as a result, schools with a breadth of scientific opportunities yield students with a strong interest in science. The study illustrated that girls who associate with science early in their lives have greater ease navigating the world of STEM in higher education (Brickhouse, Lowery, & Schultz, 2000). However, the introduction of the STEM disciplines may benefit female students more if familiarized separately from male peers, in an environment where they can explore what it means to be a scientist regardless of gender (Grossman & Porche, 2013)

Additionally, women entering STEM deal with certain external and internal influences. Masculine connotations applied to STEM fields and stereotypes imposed by others (external influence) hinder the expansion of women in the STEM professions. Unfortunately, since science- and math-based fields have gained a 'masculine' connotation, women often receive unintentional discrimination and discouragement when pursuing these fields (Grossman & Porche, 2013). Also, young women's own conflicted perception (internal influence), that STEM does not coincide with family life, misguides their construct of identity. Women in particular, when developing a certain identity, confer 'multiple possible selves' evaluating themselves on all social levels. As a result, women often feel as though they cannot break free from what makes them who they are – women. In the face of cognitive dissonance, or conflicting perception of possible selves, a woman in science often struggles to feel both feminine and confident in her STEM-related abilities (Cvencek et al. 2011). While young females struggle with lack of role models, lack of early exposure, gender biases, and internal influences in science education, young minorities face additional hurdles related to other social and economic disparities.

Minorities and STEM: In addition to low gender diversity, STEM careers have minimal ethnic diversity, as well. Maintaining its normative image, the STEM industry is predominately white. Figure 2 displays that, as of 2009, 72 percent of those who worked in STEM careers were white. With white Americans making up the majority of the field, the remaining population of STEM professionals is composed as follows: 14 percent Asian, 6 percent Hispanic, 6 percent Black, and 2 percent with other backgrounds (Beede, Julian, Khan, et al., 2011).

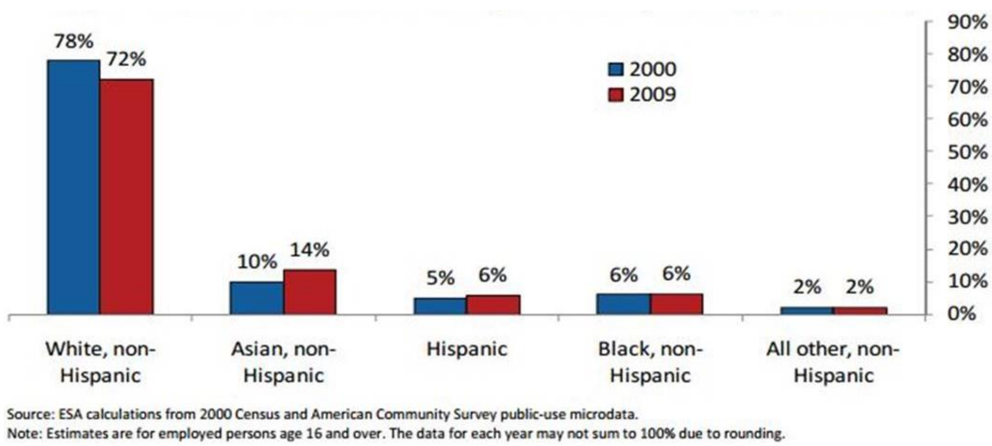

Figure 2: “Distribution of STEM Workers by Race and Hispanic Origin, 200 and 2009” (Beede, Julian, Khan, et al., 2011)

Essentially, minorities constitute less than 30 percent of STEM jobholders. The trend has continued as only 20 percent of Latino and African American students (the most underrepresented minorities) who report interest in pursuing STEM careers post-high school graduation complete a bachelor’s degree in STEM within five years (Martin and Scott, n.d.). However, the trend of underrepresentation appears much earlier than the professional and

Baccalaureate level. Researchers have begun to focus on K-12 studies assessing the structural barriers and lack of equitable educational and academic resources, as it is likely underrepresentation is a result of insufficient exposure. In particular, the education system hinders minorities as they receive subpar attention and experience necessary to envision themselves performing successfully in STEM careers (Steinke et al., 2009; Wilson et al., 2015). The expectations of performance from the underrepresented minority groups are low, which is evident in the minimal high school preparation for higher education but also in the lack of resources for support and encouragement. As children are molded by their experiences in social institutions (e.g. academic, peer, family), their self-efficacy takes a toll. Without the ability to recognize and address low self-efficacy in its critical developmental period of middle school aged children to adolescents, educational institutions cannot effectively target and engage the population in demand (Wilson et al., 2015). Positive self-efficacy translates into the motivation, positively defining life-choices and the ability to strive for achievement and maintain high academic standing. Therefore, when stereotypes surrounding minorities are further reinforced through lack of representation, the low self-efficacy cycle will continue (Wilson et al., 2015). According to the Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline, society holds minorities to low expectations in performing such higher-level tasks due to personal opinions toward race (National Research Council, 2010). As a result, race/ethnic background may impede students from academic and career opportunities.

Without a presence or dominating force supporting the empowerment of young girls and minorities to pursue STEM careers, they will continue to be underrepresented. For both populations, it is the inability to align and protect one's self-efficacy to a level of self-confidence necessary to pursue a STEM career. As all children (male, female, white, non-white) begin to define “self” at a very young age, erasing these barriers and incorporating STEM curriculums at impressionable ages is critical to addressing our national need (Foltz et al., 2014).

2.2 STEM Education

The STEM fields are growing and are shaping our society. They are growing faster than the population of students studying and training to work in these fields, leading to an increased need for STEM professionals (Vilorio, 2014). In order to be a competitive global force, the United States must emphasize STEM and broaden the flow of students into the STEM pipeline (Adkins, n.d.). This expansion means increasing diversity and highlighting STEM education with children. STEM education is most impactful when children are exposed to STEM topics early in life.

2.2.1 Why is STEM Education Important for Children?

There are a dearth of people going into STEM professions and widespread misconceptions about the abilities of women and minorities in STEM. Early and regular exposure to STEM subjects may help to alleviate these barriers.

Children are at the greatest risk of being affected by external influences. During critical transition periods, such as early adolescence, children often embody social norms as they begin constructing their own schemas, or ways of thinking about the world (Grossman & Porche, 2013). As a reflection of society, children also begin to internalize their own perceived ability as well as possible growth (Sanders, 2008). In such a critical developmental period in a child’s life, the advancement of one’s self-efficacy – or confidence in their abilities – motivates future career choices and increases their ability to see themselves as successful in STEM fields. Through STEM integration, teachers increase the breadth of knowledge provided to students surrounding the STEM disciplines, which can open doors for higher-level thinking and increased opportunities (Moorehead & Gello, 2013).

2.2.2 Efforts to Implement STEM

At a societal level, no simple solution exists for giving children complete access to STEM programs. Many children from financially stable families have access to STEM programs through well-funded schools, fee based summer camps, tutors, or specialized programs (Basham & Marino, 2013). However, many nonprofit and community organizations have worked to fill in the gaps so STEM education is available to all, regardless of financial ability. Some of these programs and organizations include Project 2061, Club Invention, and the Boys & Girls Club of Fitchburg and Leominster.

Project 2061: The American Association for the Advancement of Science founded Project 2061 in 1986 to help schools improve science, math, and technology literacy in the United States. This coincided with Halley's Comet, which will not be visible again from Earth until 2061. By 1986, members of the Association noticed a decline of science literacy of the average United States citizen and wanted to start a project to improve literacy by the next time the Halley's Comet would be visible. By 2061, the Association wanted to assure that students are able to participate in a culture that is driven and shaped by technological advances and scientific research (Nelson, 2002). To do this, the members of the Association worked together to create a national set of standards for science. This set a benchmark that many states adopted (Koppal & Caldwell, 2004). In doing this, Project 2061 affected many students by making sure that educators had access to standards and teaching materials that showed to be successful nationally. Project 2061 provides curricular resources for teachers, runs workshops to train teachers, and provides tools for the assessment of scientific ability (Nelson, 2002).

Club Invention: Backed by the U.S. Patent Trademark Office and the Collegiate Inventors Competition, Club Invention is a nationally accredited summer camp/afterschool program. Club Invention is a facilitated enrichment program sponsored by numerous businesses, which allow for high-quality immersion in the sciences (Club Invention, 2015).

The overarching goal of this program is to generate children's interest in science-based learning through fun and innovative approaches. This camp style program allows children to "explore, create, and invent," and is sustainable in its success as seen through continuous high enrollment numbers (Club Invention, 2015). The curriculum includes group-based projects to teach children the importance of teamwork. A key to success in programs such as Club Invention is the integration of knowledge as well as collaboration among students. Camp participants are given situations where they must think "outside the box" in order to test boundaries and discover on their own pace. Having this creative freedom in group dynamics allows program participants to learn hands-on and firsthand.

Boys & Girls Club of Fitchburg and Leominster: The Boys & Girls Club of Fitchburg and Leominster (BGCFL) located in central Massachusetts that provides cutting-edge STEM for its students. In 2011, the Club founded its FIRST Robotics Competition (FRC) team, called the TerrorBots. FRC is an international competition where teams of high school students are given six weeks to design and build a robot – which may weigh up to 120 pounds and stand as tall as five feet – based on game rules set by FIRST (US FIRST, 2015). Additionally, in 2013 the Club established a FIRST Lego League (FLL) team (Roberge, 2013).

Similar to FRC, FLL is an international competition; however, its design pertains to middle school students. The competition has two parts: a robot and a project. Each year, FIRST releases a themed playing field with multiple tasks for which a team must program a LEGO

Mindstorms robot to complete. The second part is the project, where team members must devise a solution to a problem related to the theme. In this project, students must collaborate and brainstorm each member's creative ideas, and nontraditional thinking is encouraged. As a whole, FLL teaches teamwork, critical thinking, and allows students to use LEGO pieces creatively to solve problems. The BGCFL is one of the first Clubs in the region to facilitate robotics teams for both middle and high school students. The Club's FLL and FRC teams compete in regional and national competitions. In many of these competitions, students have been recognized statewide and acknowledged for their great work, showing the Club's success. By hosting both of these teams, BGCFL's successful STEM programs encourage and support the integration of STEM providing students opportunities for creative engagement with robotics. The success in the robotics programs spread and, in 2014, BGCFL promoted further STEM education by holding a Science Festival ("Full STEAM ahead!" 2014).

Through continuous implementation of STEM-related programs, organizations like the Boys & Girls Clubs introduce students to the fields. Each club or program has a unique way of facilitating a breadth of learning styles and techniques for integrating STEM to their students. All three of these programs proved successful, but for different reasons. Project 2061 attacked the problem of science and technology illiteracy by providing national resources and guidelines which educators may use to improve the national level of science and technology literacy. The Boys and Girls Club of Fitchburg and Leominster and Club Invention attack this problem in a different way: by giving more students access to programs which promote high level thinking and stimulation outside of the traditional classroom. BGCFL does this by providing various seasonal programs and encouraging students to think "outside the box". Club Invention also promotes thinking "outside the box" in group and non-traditional classroom settings. This encourages teamwork between students and fosters creative thinking. Whether these programs focused on the educator or the students, all three programs considered how teaching and hand-on STEM activities are essential in making successful STEM programs.

2.3 How Do Kids Learn?

Programs like Club Invention have reported high numbers of enrollment and boasted a 90-percent approval rating from previous camp attendees (Club Invention, 2015). With high engagement through hands-on learning activities, mirroring these tactics may increase educational value and engagement in STEM topics.

Illustrating the importance of STEM education is an easy task, but the challenge arises in implementing a program that sparks interest in children. Kids learn best when the teaching style targets their personal learning styles, when they feel a sense of safety in the classroom, when they are given the opportunity to tinker, and when they are in a cooperative learning environment.

2.3.1 Gardner's Theory of Multiple Intelligences

In order to learn more about students' personal learning styles, Howard Gardner, an American developmental psychologist, developed the theory of multiple intelligences. According to Gardner, all people have different avenues of processing information, which Gardner called "intelligences". There are seven main types of intelligences, which include: (1) linguistic intelligence, related to spoken and written language; (2) logical-mathematical intelligence, related to analyzing problems logically with numbers; (3) musical intelligence, using music and musical qualities; (4) spatial intelligence, related to recognizing and mentally picturing spatial patterns; (5) bodily-kinesthetic intelligence, related to using one's body as a means to solve a problem; (6) interpersonal intelligence, related to understanding the intentions and motivations of the people around oneself; (7) and finally intrapersonal intelligence, related to one's ability to deal with oneself. Every person has a unique mix of these intelligences, which leads to knowing how one learns most effectively (Medeiros Vieira, Ferasso, & Schröeder, 2014).

Considering the different possible intelligences through which children learn is crucial to developing relevant teaching strategies. If teachers utilize appropriate engagement tactics, they can expose students to STEM in a multi-faceted way. However, without accommodating the learning environment, children may not reap all of the possible educational benefits.

2.3.2 Safety and Attachment

To progress in their education, students must have a sense of safety in and attachment to their classroom environment. Students who feel physically and physiologically safe in class, especially those in at-risk populations, are more likely to step out of their comfort zones to take academic chances that, in return, will increase their metacognition and educational success (Heydenberk & Heydenberk, 2007). Students are more engaged in classes when their peers and teachers treat them with respect, and feel accepted and liked by the teachers and classmates. A student's feelings of attachment to their class directly correlate to the amount of time and effort that he or she contributes towards the class (Heydenberk & Heydenberk, 2007). Once a school is able to create a safe, welcoming and accepting environment, it can develop a STEM program and have an increased likelihood of success. A hands-on STEM curriculum that allows students to explore and experiment with available resources will allow students to engage fully with their learning environment, teachers, and peers.

2.3.3 Tinkering

Tinkering – the act of hands-on experimentation – is important in a math and science classroom environment because it allows students to make their own discoveries by physically touching and manipulating objects. The act of *doing* is more beneficial to the learning process than the current traditional lecture-style classroom setting (Gabrielson, 2013). Beyond simple manipulation, tinkering allows students to understand and transform the lessons in a way that is more compatible to their learning styles. When students have an opportunity for hands-on learning, they make their own discoveries and face their own challenges that might not be so apparent in a lecture-style setting. For example, when learning about Newton's Laws of Motion, students will enforce their knowledge when performing simple experiments demonstrating each law, supplementing their level of understanding. Tinkering should be completed through group work, as it is an efficient means in teaching children about the STEM subjects. Group work is best performed when divided based upon gender. Stereotypically, boys are expected to excel in technology and workshop based activities, so if girls were to be placed in the same group, the boys may take over and the girls may not learn as much (Gabrielson, 2013). Thus, in order for girls to look past the stereotypes and recognize their abilities in the STEM subjects, they must be given the opportunity, through girls-only groups, to reach their maximum potential.

New technological advances, such as 3D printers, Arduinos, computer programming, and robotics are being embraced in classrooms, thus turning students into makers (Martinez & Stager, 2013). *Invent To Learn: Making, Tinkering, and Engineering in the Classroom,* by Sylvia Martinez and Gary Stager, emphasizes the idea that children are natural tinkerers, and with direct exposure to materials, their educational possibilities broaden beyond what a lecture-style classroom can teach. It is when they are exposed to tinkering where their most crucial learning takes place. Martinez and Stager describe that learning is best acquired through design, building, and engagement. For example, if children are learning about circles, reinventing the wheel will better the students' understanding of circles (Martinez & Stager, 2013). Thus, by bringing active learning in the form of tinkering, making, and engineering into all classrooms, also known as the maker movement, children pursue progressive education.

2.3.4 Cooperative Interaction

A 1981 meta-analysis of 122 cooperative learning studies conducted by David W. Johnson, a social psychologist, and his colleagues Maruyama, Johnson, Nelson and Skon found that academic productivity and achievement is highly promoted in students when placed in a cooperative environment, rather than a competitive/individualistic setting by 60-80 percent. One of these studies randomly selected 45 students and assigned them to either an individualistic, cooperative, or competitive classroom environment. The students placed in the cooperative environment outperformed the students placed in other classroom environments in tasks that involve problem-solving techniques and a higher order of thinking (Heydenberk & Heydenberk, 2007). This leads to the indication that cooperative environments may solely benefit students with lower academic ability but that is not the case. Higher ability students also benefit because they develop skills while helping those that are trying to understand. In fact, this study discovered that all students cognitively benefit when placed in a cooperative setting. When tested individually on a series of critical thinking tests, students of higher academic ability that were placed in a cooperative setting consistently outperformed the students of higher academic ability placed in individual/competitive setting (Heydenberk & Heydenberk , 2007).

Ching-Ching Cheng, an associate professor at the Graduate Institute of education at Providence University, Pei-Li Huang, a high school teacher, and Kuo Hung Huang, a professor and chairman in the Department of E-learning Design and Management at National Chiayi University, conducted a study located in southern Taiwan that tested the effectiveness of cooperative learning environments during the year 2013. They implemented a cooperative learning environment in a LEGO Robotics project that explored the effectiveness of grouping children in LEGO activities based on their family backgrounds and gender. The study suggested that model building positively affected the learning process of the math and science subjects (Cheng, Huang, & Huang, 2013). The 179-targeted students came from grades three to six and were attendees of nine different elementary schools located in central and southern Taiwan. Cheng, Huang, and Huang held weeklong camps at each elementary school and a team of college students assessed the project outcomes. They selected equal numbers of girls and boys, categorized as either average economic status or under-privileged. An underprivileged status "was defined as students from low-income, single-parent, foreign parent, or indigenous parent" (Cheng, Huang, & Huang, 2013).

Results of the implemented cooperative learning environments show that gender, age, and family background have no effect on the students' learning outcomes, but rather on the effectiveness of communication and achievement within the group setting (Cheng, Huang, & Huang, 2013). Groups of the same gender were more willing to communicate with one another as opposed to a female-dominant group where boys portrayed little interaction with the girls. In addition, during programming activities, 'underprivileged' groups lacked communication and cooperative interaction compared to the 'normal' family background groups. Assembling and programming performances directly correlated with the students' interaction with one another. Overall, the groups with the highest performance scores were the groups that had the highest rate of group interaction (Cheng, Huang, & Huang, 2013).

2.4 Need for STEM in Worcester

In Worcester, which, as of the 2010 U.S. Census, consists of approximately 183,000 people, children make up roughly 27 percent of the population (U.S. Census, 2010). Compared to the rest of the country, the Worcester youth are exposed to over five times more crime than the national average as well as an 18-percent poverty rate (Neighborhood Scout, 2015; City-Data, 2013). Although the city of Worcester boasts nine colleges, the college readiness level of graduating seniors from Worcester Public Schools is alarmingly low. Between the seven high schools in Worcester, the college readiness reported in 2015 averaged below 24 percent ("Massachusetts School Districts", 2015).

Based on the previous statistics, the educational quality within Worcester has room for improvement. In turn, effective STEM programs are critical to enhancing the academic prosperity and opportunity of Worcester's youth.

2.4.1 The Boys & Girls Club of Worcester

In central Massachusetts, the Boys & Girls Club of Worcester (BGCW) strives to promote educational achievement and contributes its ideals to the community (Foundation for the Future, 2013). The children at the BGCW rely on its services. After stepping off their school buses, the children complete homework with help from one of the hundreds of volunteer members or staff at the Club. The staff and volunteers trained in academic and emotional support make up a crucial part of the children's experience as these workers connect with the youth as role models (Foundation for the Future, 2013). The dynamic of the Club allows children to drive their own academic achievements by choosing their own educational activities. As a result, students are not bound to the programs they choose and may only stay if they find interest in the topics of the program.

The BGCW currently works with over 130 children from a wide array of backgrounds. The Club's 2012 reports indicate that 64 percent of the youth live in a single parent home and 80 percent of its children live below the national poverty line (Foundation for the Future, 2013). As a result, the Club offers a low registration fee of $25 per year and welcomes children of all backgrounds. The efforts of the BGCW influence 6,000 Worcester neighborhood youth per year.

However, Worcester houses approximately 48,000 children, meaning that tens of thousands of children do not receive assistance from the BGCW programs (US Census, 2010).

By providing educational assistance through homework tutoring, college advising, and other similar programs, the BGCW provides thousands of children in Worcester with the opportunity and room to grow and prosper. Each year, over 90 percent of the youth that leave BGCW become college graduates. In fact, in 2013, 97 percent of BGCW high school graduates went on to college (Foundation for the Future, 2013). This statistic far surpasses the 20 percent of Worcester public school students who reported intentions of attending a four-year college (Worcester by the Numbers: Public and Charter Schools, 2014). Students from the BGCW do not only leave and attend one of the nine surrounding Worcester colleges; they are also branching out to four-year institutions across the nation. As an outlet for the at-risk youth in the greater Worcester population, BGCW strives to be an active model organization in the Worcester community.

The BGCW recognizes the importance of STEM education and strives to engage its children in the STEM fields. One such program was a six-week pilot program based on LEGO robotics that ran in the spring of 2015 (Fowling & Aponte, personal communication, September 16, 2015). Twelve students aged 10 to 12 participated in this specialized program, and the staff saw heightened engagement and interest in STEM among these participants. In turn, an idea came about to foster this interest into a full STEM education program at the Boys & Girls Club of Worcester.

2.4.2 Proposing a STEM Program to the BGCW

In an effort to build on the aforementioned pilot program, the Boys and Girls Club of Worcester decided to work collaboratively with WPI’s Worcester Community Project Center, seeking assistance in developing an engaging STEM program for implementation by the Boys &

Girls Club of Worcester. Ultimately, the hope is that the program will spark interest and excitement about STEM fields among the BGCW youth. In the next chapter, we discuss the methods by which we plan to accomplish this goal.

Chapter 3: METHODOLOGY

In its efforts to cultivate academic excellence, the Boys & Girls Club of Worcester (BGCW) recognizes the importance of science, technology, engineering, and mathematics (STEM) education. The goal of our project was to develop and implement a STEM education program to benefit the students at the Boys & Girls Club of Worcester (BGCW). In the spring of 2015, the Club implemented a six-week robotics program to fulfill grant requirements and found the program to be a topic of interest amongst the students. The staff of the BGCW and our team hoped that interest in robotics could grow into an overall interest in STEM fields, giving student participants a sense of confidence in their STEM-oriented abilities. In order to fulfill this goal, we developed the following objectives:

1. Conduct a meta-analysis of existing STEM enrichment programs working with 10-13 year old students
2. Identify preconceptions of STEM and level of interest in STEM among the 10-13 year olds at the BGCW
3. Determine appropriate and feasible learning outcomes for the program
4. Develop an implementable STEM curriculum for the BGCW that meets the learning outcomes in Objective 3
5. Prototype portions of the curriculum with 10-13 year old BGCW students
6. Evaluate and refine the program based on feedback from the prototype
7. Determine available resources and potential funding opportunities for a STEM program at the BGCW

Upon the culmination of this project, the team completed the necessary research to recommend 7-week core STEM program with additional material for expansion to be implemented by the staff and volunteers at the BGCW. We discuss each objective and our methods for achieving the objectives in detail below. Additionally, please see Appendix A for a detailed timeline of our objectives.

3.1 Objective 1: Conduct a meta-analysis of existing STEM enrichment programs working with 10-13 year old students

The team's first objective, before diving into the world of the BGCW, was to research the types of STEM-based activities and programs that most effectively teach and excite students aged 10 to 13. A meta-analysis on these programs allowed us to assess a multitude of findings on studies about the effectiveness of the teaching styles, pilot programs, and integration techniques. The programs we analyzed took the form of a range of programs from after school care to formal classes. Through analyzing existing STEM programs, we discovered a breadth of successful ways of teaching this age group to better understand how to move forward with our project. In order to identify community organizations with STEM programs and STEM community leaders to interview, we used media coverage and respective data on central Massachusetts programs similar to the BGCW, as well as information provided by subsequent interviews about beneficial organizations to contact.

First, we interviewed several STEM program educators and facilitators to gain a better understanding of the current programs and ways of implementing them. The first STEM facility we researched and investigated was the Worcester Think Tank, a STEAM (Science, Technology, Engineering, Arts, and Math) based center where homeschooled and traditionally schooled students could take classes. We interviewed Lauren Monroe, the Co-Director and founder of Worcester Think Tank to gain insight on how her programs worked and how she facilitates the STEM education of Worcester Youth. We hoped to learn about her experience with teaching students STEM and her thoughts about the best ways to teach STEM in a classroom. (See interview questions in Appendix B).

The second program we investigated was the Boys & Girls Club of Fitchburg and Leominster (BGCFL). Through our research, we discovered that the BGCFL had a FIRST

LEGO League team for its students, as well as other various robotics teams, and hosted regional competitions for teams in the area. We conducted a semi-structured interview with the educational director, Donata Martin, because we wanted to maintain a comfortable conversation style interview while walking about the Club and viewing their program space. Since BGCFL strives to be a good example for the community with their focus on STEAM, we hoped this interview would give insight into how their STEAM programs came into prominence and how that focus impacted their students. (See interview questions in Appendix B).

Next, we interviewed Martha Cyr, director of the WPI STEM Education Center, and STEM Education Center staff member Shari Weaver, to gain their perspectives on STEM implementation. Through a semi-structured interviews, the team hoped to learn about a variety of methods for teaching STEM to young students. The team also hoped to learn about existing WPI groups or programs on campus that have taught students so we could utilize snowball sampling and expand our interview portfolio. Snowball sampling proved to be important as a means of expanding our interview pool through referrals (Berg & Lune, 2012). (See interview questions in Appendix B).

We also interviewed Dr. Deborah Harmon Hines, a community-based STEM advocate in the Worcester public school system. We believed that through her interview, we would gain insight into teaching underrepresented youth about STEM topics, and how the youth's socio-economic status may impact their perceptions in STEM. These interviews helped us understand the most important traits for having a 'successful' STEM program that encourages underrepresented youth to pursue STEM careers. (See interview questions in Appendix B).

Moreover, the team consulted Mrs. Elisa Heinricher, the director of Academic Technology at Bancroft High School, to gain perspective on useful tactics used by local high school STEM and robotics programs. Mrs. Heinricher serves as the upper school VEX Robotics faculty advisor and has a history of being an advocate in the Bancroft School for promoting and encouraging STEM programs. Through this interview, we wished to gain insight about the history of STEM at Bancroft and the successes or challenges that they faced in implementing STEM programs. Although Bancroft largely serves a different socio-economic demographic than the Boys & Girls Club of Worcester, we believed we could learn whether the Bancroft programs were successful at incorporating female students and sparking interest in the STEM topics. We would then use the information from this interview with Mrs. Heinricher to develop an approach for implementing similar programs at the BGCW. (See interview questions in Appendix B).

Furthermore, the team analyzed existing STEM programs to determine which aspects of the programs were successful in their ability to offer an accessible STEM lesson plan and sustain excitement throughout the program's duration. One such program the team decided to focus on was Club Invention, which is a summer enrichment program for elementary school students to keep them stimulated and thinking critically throughout the calendar year. Since Club Invention takes place in several locations in central Massachusetts, finding a branch nearby was easy. We reached out to and interviewed Tricia Desmarais, who is the Director of Camp Invention formerly at WPI, now in Millbury. Through this interview, we wished to gain insight on how the local Camp Invention chapter conducts its programs, and how they keep students engaged and stimulated throughout the summer seasons where there is usually a decrease in academic involvement. (See interview questions in Appendix B)

As an additional source of information and to network with Massachusetts STEM professionals, we attended the Massachusetts Stem Summit 2015, an annual conference that promotes STEM education and professional development in order to place precedence on early intervention in STEM education. Through attending sessions on K-12 STEM Education, the team wished to gather more information about possible programs or organizations to research. Additionally, multiple sessions gave us resources for curriculum, ideas for possible projects, as well as insight and suggestions applicable to our project. We also spent time in the Exhibit Hall, where we were able to speak with representatives of organizations we had previously contacted, such as Club Invention and PBS, to gain extra information on their current programs.

Finally, to explore the effectiveness of certain techniques used by STEM programs on elementary school aged youth, we consulted case study research provided by speakers at the STEM conference. The case studies compared successful and unsuccessful STEM activities as ways of integration. Robert Yin, expert on case study research, explained that case studies are often the best items to use when attempting to gain understanding of an in depth social phenomenon, such as STEM education, as well as how and why it may work in specific social settings (Yin 2013). Through this consultation, we were able to identify teaching/learning methods deemed successful or unsuccessful by means of evaluation over a period of time (surrounding the program), as well as any learning outcomes tailored to the program relative to the specific social setting or demographic of students. This form of research helped us understand possible limitations as well as long-term benefits that other STEM programs have experienced through teaching techniques and program patterns.

3.2 Objective 2: Identify preconceptions of STEM and level of interest in STEM among the 10-13 year olds at the BGCW

The team's second objective was to identify the current state of preconceptions and interest surrounding STEM among 10-13 year old children at the Boys & Girls Club of Worcester. Similarly, we identified the Massachusetts Common Core learning standards, taught within the classrooms of the prospective students, and also determined common interests and aspirations for the implemented program. Past research has shown that social and academic settings exhibit the internalization of stereotypes, and without first understanding the perspective of the children, instructors are unable to tailor beneficial programs and curriculums (Cvencek et al., 2011). In particular, the most apparent and detrimental stereotypes which influence children are those present in their educational infrastructure. For example, the perception of the stereotype that women and minorities are unable to achieve successful in such challenging disciplines is directly related to the underrepresentation of these populations in the STEM fields. With an organization such as the BGCW, we must consider that members came from various ethnic backgrounds including: Asia, Eastern Europe, Middle Eastern countries, and the Caribbean. Therefore, in order to gain a better understanding of the preconceptions and stereotypes that may influence or hinder the academic achievement of the youth at the BGCW, we addressed the issue directly with the children. Through the focus groups and individual discussions with the students, we learned the challenges/preconceptions that they face relative to math and science. We asked the children to describe whether they found interest in their math or science subjects and to provide any additional information that weighed in on their opinion. For example, we offered students the opportunity to answer, “What do you want to be when you grow up”, and we translated responses and feedback into findings surrounding the preconceptions and interest of the BGCW members.

To coincide with this information and provide an optimal learning environment, we assessed current learning standards within the science and math classroom. This allowed us to tailor the STEM curriculum we were developing to the members of the BGCW and their academic learning standards.

We conducted a range of participant observations, small focus groups, and semi-structured informal interviews in order to understand the environmental influences, interests, and professional hopes of BGCW members. The participant observations allowed us to remain unobtrusive in our method design and acquire qualitative data in the form of personal interactions and natural observation. We noted members' behaviors and attitudes towards their environment and peers, and general interests among the middle school population within the Club.

Second, we held small focus groups to gain unbiased opinions and emotional perspectives of the children who may attend the fully implemented STEM program. Along with understanding any possible preconceptions, we also held focus groups to assess the specific learning standards being taught inside of the children's classrooms as well as noting all ideas and interests the children expressed to include them in the program curriculum. These sessions allowed us to note how the children at the BGCW function in small, facilitated groups, especially in a co-ed manner. We noted the behaviors of the children towards peers, as well as physical body language and expressions as an assessment of the environment. In his understanding of focus group methodology, Richard Krueger distinguished this process as rather informal but extremely personal (Krueger & Casey 2002). In order to perform these styles of interviews, we considered certain aspects of the cohort. As Krueger explains in his work, we recruited participants in small numbers, 5-10 (possibly 4-6 with children) from a similar cohort based upon similarities and precedence (Krueger & Casey 2002). At the BGCW, we sought out members currently in, or entering middle school, because they were the target audience of this program. We took detailed notes during these group interviews for later translation and data analysis in order to better adapt the curriculum to the preconceptions of the children and their interests. We hoped that by tailoring the curriculum to mirror standards within the classroom, students would be able to make the lessons relevant and real. We collected responses from both focus group discussions and honed in on the major themes and responses that influence the environment and express interest for the program. (See focus group discussion topics in Appendix C).

We experienced some challenges in conducting the focus group. The first obstacle we faced was in dispensing the parental consent permission slips as it took numerous days to retrieve any signed forms (see Appendix F for examples of the permission slips we distributed). Once the children had parental consent, it was crucial to remind the children constantly of upcoming focus groups and pilot sessions to ensure clear communication of pickup and drop off times. Entering the sessions, we knew that the discussion would have to remain interactive, so we bolstered our conversations with interactive activities. However, we still encountered obstacles along the way. At times, it was difficult to maintain the kids' attention. We understood that children ages 10-13 are easily distracted and would be more engaged with active learning. Therefore, we used interactive activities, enthusiastic discussion points, and snacks, to facilitate the conversation and retain the children's attention.

As a result of the focus groups and interviews, we were able to identify potential challenges we needed to consider the design of the program. The feedback we received from the focus groups helped in our thought process of the program's curriculum, as we would tailor parts of the program to students' preferences. With this in mind, we began developing the outcomes and objectives of the program.

3.3 Objective 3: Determine appropriate and feasible learning outcomes for the program

Following the majority of our interviews and immersing ourselves in the BGCW, we began the curriculum-building process by identifying appropriate and feasible learning outcomes for the program, which are the abilities students' exhibit or demonstrate at the end of the program. These are useful in structuring the program as it lays out what we expect the children to come away with. To do this, we used information from our interviewees and consulted online sources that laid out certain outcomes for existing STEM programs. In each of the interviews with STEM educators, we asked about learning outcomes for STEM programs in which they were involved.

In addition to the information we received through interviews, we also utilized online resources to help develop the learning outcomes. These resources offered insight into the learning outcomes of various STEM programs. One item of particular interest was a report published by the Afterschool Alliance. This report displayed a study of 55 afterschool providers and 25 afterschool STEM supporters that culminated in a consensus set of learning outcomes for an afterschool STEM program (Afterschool Alliance, 2013). Additionally, this resource provided a set of indicators to support these outcomes. The coupling of interview responses and online research helped us develop the learning outcomes for the BGCW STEM program.

3.4 Objective 4: Develop an implementable STEM curriculum for the BGCW that meets the learning outcomes in Objective 3

Using the learning outcomes developed in objective 3, we strove to build a curriculum that would ensure the program participants would achieve these outcomes. The responses from the focus groups conducted in Objective 2 provided a comparative analysis of the preconceived notions toward STEM among the children at the BGCW. We learned about areas of STEM in which the students can grow as well as certain STEM topics in which they have high interest. Additionally, we used the information acquired from the semi-structured interviews with STEM advocates and educators to help us design an effective program. Furthermore, we consulted free online STEM resources to adapt pre-existing lesson plans to the needs of the BGCW. We have included a list of these sources in Appendix D. Through a comparison of these responses, we developed a prototype of STEM related curriculum that filled the gap present in the BGCW environment.

When developing the STEM program, we considered certain factors. One important item was that the program attendees were respectful of one another and maintained a positive atmosphere while participating in program activities. In speaking with BGCW leaders, we understood that previous STEM program leaders struggled to maintain the undivided attention, and explored different methods for increasing focus and concentration of the program participants.

We experimented with competition based on a study that Lisa Smith, a kindergarten teacher, and Susan Fowler, a third grade teacher, both at Greenbrier Elementary School located in Greenbrier, Tennessee, conducted experiments that integrated a token system in a behaviorally impaired kindergarten class (Fowler & Smith, 1984). To maintain a well-behaved environment, we experimented with a token system in which student received an award for their active participation and positive behavior. For our small pilot sessions, the children received a prize for the winning team, and candy for participating in the full session.

3.5 Objective 5: Prototype portions of the curriculum with 10-13 year old BGCW students

Due to time constraints of the project, we will not be involved in the full implementation of the STEM program. However, in order to test the effectiveness of the curriculum, we piloted parts of the program. Before beginning sessions with BGCW members, we pre-tested the pilot sessions with WPI students due to their easy access and availability on short notice. Once the kids returned their permission slips, we began our pilot. With the aid of Tomas Aponte, the education director and our sponsor, we invited children that had received parental consent and were within the 10-13 age range. In these sessions, we led the activities with Mr. Aponte present so that he could remain in authority, and intervene if necessary. When conducting the sessions, we also acted as observers. Two team members had the task of observing portions of the session and taking notes, while the other two team members focused on instructing the class and maintaining class discussion. Based on the article "Assessing Student Engagement Rates" within *ERIC Digest,* we established a set of key focal points to observe such as positive emotional engagement, and willingness to apply thoughtful, strategic, and creative knowledge to the task (Chapman, 2003). Visually, we observed the strong and weak points of the curriculum based on engagement. In order to assess the level of engagement among participants, we consulted the same assessment of effective learning, which illustrates specific behaviors to observe relative to high levels of enthusiasm (Chapman, 2003). The criteria and key points we used to assess the pilot session can be read in detail in Appendix E. With this information, we adjusted the curriculum in an effort to create an effective and engaging program for the BGCW to implement.

In addition, we used a combination of discussion-based and written evaluations to assess the learning outcomes of each pilot session. We wanted to be sure that the activities met the standards of the learning outcomes. If the students' assessments did not align with the indicators of the learning outcomes, we would refine the activities to fill the gaps.

In addition to our own observations, we conducted pre- and post-pilot evaluations that not only assessed participants' previous knowledge and interest in STEM, but in the end allowed open responses for their reactions of the pilot sessions (see Appendix G for pre and post evaluation). In this assessment we gave the children a simple evaluation sheet that would not only provide us with interest level and feedback, but also grant the Boys & Girls Club additional information surrounding their members. Other social research studies have used this tactic of self-report responses, and it remains beneficial when assessing 'successful programs' (Chapman, 2003). To distinguish 'successful' characteristics of the pilot program, the group consulted information about the evaluation techniques used by successful STEM programs acquired in Objective 1.

The data compiled through observation of the pilot sessions, feedback from our sponsor, and learning assessments helped us make the necessary revisions to improve the program.

3.6 Objective 6: Evaluate and refine the program based on feedback from the prototype

Based on the results of the prototype sessions and subsequent post-pilot focus group, we evaluated and refined the program. We accumulated responses from Mr. Aponte and children of the BGCW who participated in the activities. We had distributed a pre and post short self-report assessment that asked the students to check activities they felt were most interesting to them. By assessing the pre- and post-evaluations administered in each pilot session, we were able to gauge if the students fulfilled the learning outcomes for that session. For example, we asked the students to fill in the acronym STEM before the program began, and again at the end. We felt this would be a subtle indicator that the students paid attention during sessions and increased understanding in the meaning of STEM (Science, Technology, Engineering, and Math). This example can also be found in Appendix G.

After assessing the effectiveness of the pilot sessions, we modified and improved the program curriculum to prepare for its launch in the spring of 2016. At the culmination of this project, we left the BGCW with a 7-week long curriculum per request of our sponsors (bolstered with back-up lessons to permit flexibility) focused on STEM. We also provided the BGCW with detailed instructions and resources for implementing the curriculum. This curricular design will allow future volunteers to conduct lessons seamlessly and informatively. We share the details of the curriculum we designed and the rationale for it in the subsequent chapters. The next chapter explains our findings and suggested recommendation regarding the program.

Chapter 4: FINDINGS & RECOMMENDATIONS

4.1 Best Practices for STEM in Urban Youth

When synthesizing the accumulated findings, we noticed that the information fell into categories, which addressed larger, more complex topics. The majority of our initial information and research came from online resources and archival data. Then we generated findings from interviews and group discussions with STEM advocates and educational experts within the area. These findings, organized within the topic of *Best Practices for STEM Integration with Urban Youth*.

Finding 1: Children learn best through hands-on learning activities

Hands-on learning centers on an educational approach that benefits almost all children within a classroom. Using physical manipulation and 'tinkering,' students are able to learn more from the material, and begin to understand their own learning style. It also allows students to appreciate their own responsibility in the learning process and their most beneficial individual learning style. This finding was consistent among all interviewees and consulting sites during our process.

During the pilot sessions, the children clearly displayed a wider range of learning experience. Once given the opportunity to ruminate on the topic at hand, the kids' level of comprehension came to the forefront. When discussing the teaching styles of urban youth programs with Dr. Harmon Hines and Mr. Layne, we found that increasing children's exposure to these topics by presenting the information and materials interactively can help boost their understanding of STEM. One of the strengths of the widely successful STEM enrichment program, Camp Invention, is that it utilizes hands-on, experiential learning. The local Director of Camp Invention, Tricia Desmarais, expressed the necessity for manipulative lessons that increase children's understanding through their own connection with materials. From her insight, we understand that without being able to physically manipulate the world around them, children may develop a disconnect between what they are taught, and how much they truly understand the subject at hand. It is crucial that children have access to varying teaching styles as well as increased exposure reinforced through lesson plans. As their ability to connect with their work grows, students are able to increase confidence in their own intelligence, as well as their ability to become successful in challenging job fields. Through the process of "tinkering", children can begin to build connections and understanding with the material at hand, ultimately reinforcing the responsibility they have over their own learning process and their understanding of the material (T. Desmarais, personal communication, November 2, 2015; Gabrielson 2013). In recent interviews with STEM educators and advocates within the Worcester community, it was evident that experts in the field rely on the use of hands-on learning in their own classrooms to foster engagement and attention in children ranging in ages. Lauren Monroe, Co-Founder of the Worcester Think Tank (a makerspace offered to students and teachers in the STEM disciplines), generously spoke with us about the success of her business and what she has been able to offer to the Worcester community (L. Monroe, personal communication, October 27, 2015). She grants a physical space to incoming teachers willing to take on a set of students outside of the traditional classroom setting. When asked about the relative success of the lessons and instructors working within the Think Tank, Ms. Monroe stressed the importance of hands-on learning for numerous reasons. In her makerspace, hands-on learning is one of the few ways that children are able to tackle jobs and projects with updated technology and tools they have never used before. She believes that the hands-on, experiential nature of their learning allows students to have responsibility over not only what they are physically working on, but also the process by which they learn. In our research of Howard Gardner's Theory of Multiple of Intelligences, we recognize that children learn in varying ways or avenues in which they process and understand information. It is clear that children may range across a number of these seven different learning styles (e.g. spatial or bodily-kinesthetic intelligences) (Medeiros Vieira, Ferasso, & Schröeder, 2014). In consideration of this information, local STEM professionals feel that urban youth in particular are hindered in their ability to express or gain responsibility over their own learning styles primarily because the public schooling system does not have the resources/support to provide lessons tailored to specific learning styles such as hands-on, experiential learning. Tricia Desmarais, the local director of Camp Invention in Worcester, expressed similar sentiments explaining that lessons should be “relatable as well as imaginable”, and that it is necessary for teachers to foster creative and curious environments (T. Desmarais, personal communication, November 2, 2015).

Based on these and other interviews discussed later, it is clear that STEM educators and professionals feel strongly that hands-on, experiential, and project-based lessons will allow students to get the most out of their STEM education. Hands-on learning provides physically interactive lessons that involve manipulation of materials and educational tinkering by means of the scientific method. Experiential, project-based learning is where the hands-on learning is transformed into hands-on engagement applied to the intellectual problem; students are able to work independently or collaborate with peers to solve a problem or complete a task. For urban youth in particular, these avenues of hands-on lessons supplemented with project-based learning, makes the lessons relevant and worthwhile because they are able to make connections on their own experience. The pilot sessions conducted with the children at the BGCW reinforced our understanding that hands-on learning was best when implementing a STEM program. Children expressed their excitement and fascination towards being able to complete the task themselves, and they made connections to the lessons by demonstrating their abilities to complete the tasks. Students took the all-encompassing lesson plan and produce creative ideas and discussions centered around the topics in the pilot sessions. The children were increasingly proud of their independent products and took home their finished inventions to share with those at home (e.g. handmade hovercraft). The children continued to express their creative ideas and enthusiasm for the future program.

Finding 2: Urban youth can relate to the STEM disciplines when the lessons are relevant to schoolwork and apply to real-world situations

Connecting the real world application of STEM to the learning experience is critical for urban youth who struggle to relate to the STEM discipline. They will benefit more when lessons are cohesive with theory and application. In order to increase understanding of the STEM disciplines, and increase the student's ability to connect with the STEM job field, lessons should be relevant to their academic schoolwork and applicable to real-world situations. STEM educators who devote their work to introducing STEM to the next generation have found it necessary to include curriculum topics that are both relevant to the common school curriculum and coincident with present real-world situations. Dr. Deborah Harmon Hines, the Vice Provost of School Services at the University of Massachusetts Medical School, stressed the impending need for introducing STEM to the urban youth in the Worcester community. Similarly, her co-worker Mr. Robert Layne, Director of the Worcester Pipeline Collaborative, a STEM movement, recognized the importance of the work that the BCGW is doing to bring STEM into the organization, and particularly noted the necessity for relevance within the curriculum. He insisted that if the kids cannot connect the activities to real-world situations, then the students would lose interest. Both professionals expressed that without relevant lessons applicable to school or everyday life, children will not be able to understand the lesson and how it may relate to professional success later in life.

Many STEM educators who touched upon this point, expanded on curriculum ideas that involve concepts of exposure, experience, and understanding. By providing students with lessons that are relevant to their schoolwork, or coincide with the Common Core standards of that state, interviewees noted that students are able to increase achievement and understanding, within school, when lessons reinforce what they are learning within their traditional classroom. Students in the state of Massachusetts, in particular students within Worcester, attend classes (both public and private) with curriculums held to the Massachusetts Common Core and The Next Generation Standards. Therefore, when creating a curriculum for STEM integration in an out-of-school program, particularly in an urban youth community, we found that it is crucial to make sure students are able to apply what they are learning to the real world, but also relate to the academic content they are getting within the classroom.

We also had the opportunity to speak with Donata Martin, the Executive Director of the Boys & Girls Club of Fitchburg and Leominster (BGCFL), a very similar organization dedicated to the spread of STEM education and early intervention in science and math. When speaking with Ms. Martin, we were able to gain a perspective of a very similar organization devoted to the spread of STEM education and early intervention in science and math. Widely known in its community as a successful organization that promotes child involvement in STE(A)M, the BGCFL has spearheaded efforts to tackle the national deficit of early introduction to STEM topics and made STEM its number one priority. Ms. Martin believes that “Science is the way of the future”, but recognizes the present lack of STEM integration in most children’s lives. Ms. Martin knew she wanted to offer something different in Leominster. She went on to explain that the success of many of her numerous programs offered at the BGCFL come from the real world application. For example, her students have recognized the importance of agriculture and the ‘growing’ need to supply our own food. Therefore, they created a community garden at the BGCFL where they regularly sell products at local farmer’s markets. This is just one of the many community-based, real-world activities in which the children can participate. Since its inception in 2008, the interest in their programs is overflowing, and the BGCFL must adapt to the rapidly growing interest. The Club has grown their program membership from 25 to 500 students since they began offering STEM programs and received the support from the community. Through curriculums that interest all, children can gain and engage their own ‘STEM mindset’, and begin thinking in ways that would not be possible without first applying their knowledge to the real world. In order for the students at BGCFL to make connections with the STEM disciplines and lessons, the program curriculums are bolstered with hands-on learning components and relevant topics to our everyday life. The consensus among all of our interviewees followed in the opinion that the most important outcome is to generate interest in STEM and STEM learning activities. Specifically, Donata Martin of the Boys & Girls Club of Fitchburg and Leominster stressed the importance of “demystifying” STEM and showing that STEM is attainable. Through the successes of her programs, she has provided BGCFL members with a vast educational STEM experience. When asked how she is able to reinforce the educational value of each program, Ms. Martin proceeded to discuss the standards and evaluations that the BGCFL utilize to ensure children are maintaining (or improving) satisfactory grades in school. Ultimately, we found that through understanding the necessity to “break the box” and move away from the teaching styles of the traditional classroom, the STEM program for the BGCW must include lessons relevant to the Common Core learning standards and have real world application. Using this as a framework, we understand that lesson plans must incorporate different topics for the children to connect with the material, but it is most beneficial when program curriculums coincide with their daily academic lessons.

Finding 3: Short, thematically-connected projects that vary from day-to-day maintain children's interest and engagement

Short, thematically-connected projects that vary from day-to-day help to maintain children's interest and engagement. By presenting new content daily, children are able to sustain interest in a variety of subjects, and gain the educational value of the thematic connections between courses. The short sessions, which could supplement one larger unit, allow students to more manageably build their knowledge within a discipline, while also remaining engaged and interested. An example of lessons separated by session can be found in the lesson structure of our final curriculum (Appendix H). All STEM educators expressed that STEM programs regularly use this technique, and is thought to be one of the primary reasons for their success.

Tricia Desmarais, director of the local Camp Invention in Worcester, was quick to point out the importance of changing lessons plans, and the successes behind it. To maintain their success, the program offers changing lesson plans, such as a day filled with three-four activities (e.g. robotics, engineering, and chemistry) thematically connected to a yearly theme; this year's theme is "EPIC". The themes of the program change annually to keep children excited, engaged and eager to return. As a well-supported STEM enrichment program offered nationwide, the success of Camp Invention is well known and endorsed by affiliated students and teachers. STEM educators and advocates in the Worcester area, like Ms. Desmarais, spoke with us about their experiences utilizing and supporting this technique. In particular, Martha Cyr, the Executive Director of the STEM Education Center at Worcester Polytechnic Institute provided specific insight and opinions relative to the structure of STEM curriculums and classrooms. She devotes her work to K-12 Outreach programs in STEM integration to the classrooms, and spends a majority of her time deciphering best practices for STEM integration and informing teachers on how to model STEM integration in the classroom. Her opinions and insight complemented our research connecting the use of short thematically connected lessons with simple engaging activities. Ms. Cyr's suggestion for curriculum structure coincide with the current curriculums of successful STEM programs, and were evidenced in the success of our pilot sessions as children remained attentive through short connected lessons.

In addition to Ms. Cyr, we spoke with Shari Weaver, a member of the STEM outreach programs advising staff. Both women stressed the importance of changing lessons plans, with the necessity of a narrative thread. The narrative thread being the thematic-connection made between the lessons or units. This means that although one day's lesson may go from engineering topics, the next lesson in physics should be structured in a way that students are able to make connections between the two. This idea of making *connections* builds on our second finding, to keep the lesson plans related to the real world and relevant to school work. Short simple lessons are best for out-of-school urban youth STEM education programs because of the ability to establish connections without losing attention or engagement. In a setting where time is limited, short impactful lesson with real world applications will maintain student's interest and attention. This is extremely crucial when considering urban youth, as Dr. Hines and Mr. Layne at UMASS expressed that in their experience, urban youth maintain interest when subjects readily change but also elicit an instant connection with the lesson at hand (D. Hines & R. Layne, personal communication, November 3, 2015). This means that students who transition from lesson to lesson can make connections between activities as well as increase their understanding of the subjects and confidence in their abilities. It is necessary to maintain the curiosity and engagement of children, and varying lessons plans remains the preferred suggestion. We have found that educators who have experience in both lesson plans, such as Lauren Monroe, express that it is most successful to offer short but thematically connected lessons with the STEM disciplines to maintain student involvement and most importantly, engagement. Instead of continuing lessons in which the students may be struggling or disengaged, varying lessons plans can provide variety and opportunity.

Finding 4: Socioeconomic backgrounds do not determine the academic capabilities of urban youth

For students to thrive in their academic environments, they must be given the opportunity to challenge their knowledge to the fullest potential. In an interview with Dr. Deborah Harmon Hines, the Vice Provost for School Services at the University of Massachusetts Medical School, and Robert Layne, Director of the Worcester Pipeline Collaborative, both interviewees expressed the need for high expectations. Through her experience with urban youth, Dr. Hines discussed with us the reality of the students' lives beyond school, but stressed the necessity for equal treatment. Both professionals felt that the academic capabilities of the students they have worked with would be hindered if instructors did not give them the chance to rise to the occasion, and to challenge themselves along the way. In our hovercraft pilot session, one of the boys, in particular, was disruptive and seemed uninterested at the beginning of the activity, and thus we as a team underestimated his abilities in creating a successful hovercraft. It was not until the end of the activity where we realized that this boy was engaged in his work and was actively trying to improve his hovercraft even after the session was over. Furthermore, Donata Martin at BGCFL reiterated the importance of having high expectations for the children in her STEAM programs so they are held responsible for their learning process, but not restricted by their backgrounds. Ms. Martin and Mr. Layne also discouraged us to set lower standards in the children's academic capabilities, and to uphold Common Core standards, because in order for them to thrive in their academics, they must be placed in an environment that promotes personal growth. Challenging projects, as opposed to quick and easy activities, better engage students in their work. Using challenging components throughout the curriculum, the expectation of the students will remain high, and the level of work will allow students to challenge themselves.

Finding 5: There are conflicting ideas concerning gender separation in the classroom and in curriculum

Conflicting ideas concerning gender separation in the classroom and in curriculum arose when speaking with several STEM advocates. Specifically, STEM educators feel as though restriction may arise for female expression of ideas (hindered by male presence). Furthermore, others expressed that curriculums could be tailored to fit female and male interest specifically. We took these opinions and experiences into account when formulating our respective finding.

The STEM professionals we spoke with had their own opinions on the segregation of the genders within the program. Dr. Harmon Hines and Mr. Layne suggested that we should separate the classroom by genders because of possible distractions that hormones may pose in co-ed environments, especially in the 10-13 age range. They suggested that a co-ed environment is optimal occasionally, but that behavioral and social conflict will be less in a gender-segregated environment. Lauren Monroe, Co-Director of Worcester Think Tank, offered a different perspective. She did not recommended segregating the classroom based on gender. Rather, she emphasized that there should be a female and a male teacher present in each session, which is described in more detail in Finding 6. Similarly, Elisa Heinricher, the Director of Academic Technology at Bancroft School in Worcester, MA, felt that complete segregation is not necessary because the girls "may stay towards the back of the classroom." She explained that a STEM classroom naturally separates based on gender, where the boys usually group in the front of the class, and the girls in the back. However, we felt as though this would not allow both genders to work in a comfortable environment because of possible competition between the sexes. This could in turn reinforce stereotypes subject to women in STEM. Numerous interviewees we spoke to after expressed the necessity for segregation due to the current trends of the STEM disciplines now (white male dominant). This means that due to underrepresentation of women in the STEM fields, young girls may subconsciously feel hindered or restricted in the STEM environment. However, by providing occasions where genders can come together might help stabilize girls' potential insecurities when interacting with boys, foster confidence, increase "self-efficacy," and provide teachable moments to end competition between sexes in the future, where the sexes will share a common workplace. In our pilot sessions, the separation of genders allows for both groups to express creative ideas among themselves and focus on individual competition rather than between sexes. Once the groups were brought together, their own individually developed ideas could then be expressed in a co-ed social setting. Therefore, we found that there are conflicting ideas in the segregation of genders, but compromises in structure.

In regards to the curriculum (and necessary adaptations), Donata Martin at BGCFL, recommended that we should adapt curriculum to one gender or another because it is possible that they would be interested in different variations of science. She expressed that a lesson plan that might interest boys, may not also interest girls. However, Martha Cyr emphasized that while a single curriculum may work for both genders, it must cater to the interest of girls and minorities, since these members of the population are most underrepresented in the STEM field. She explained that certain curriculums can be made to interest all (boys, girls and minorities included), but curriculum that is tailored to interest white males might not interest girls and minorities. Due to the evident trends in the women and minority gap in STEM disciplines, we considered that dividing the curriculums might reinforce the trends. When assessing a model STEM enrichment program like Camp Invention, it is clear that programs held in Millbury, MA, can remain successful with co-ed curriculums and lesson themes. With that said, Director of the local Camp Invention, Tricia Desmarais, stands behind the curriculum that her program offers, and supported the occasional separation of genders within the program. This means that boys and girls are often separated based on activities that best interest the genders, but that the program remains successful and with high student retention by maintaining a co-ed style curriculum. Based on the interest and opinions of Joanne Fowling, the Assistant Director of Operations at the BGCW, and Tomas Aponte, the Education Director at the BGCW, we determined the best learning environment at the Boys & Girls Club of Worcester.

Additionally, regarding the pilot sessions, we held two that were gender-specific and one that was co-ed. When the boys and girls were separated, we had very few issues and saw high levels of engagement and participation. While the kids were still engaged in the co-ed environment, the atmosphere was more chaotic, and controlling the co-ed group proved more difficult than the gender-specific groups. We found equivalent interest levels within the lessons, as well as success in the separation of genders. Students were able to have a consistent flow of discussion amongst themselves; free of external influences possible when teaching a co-ed student body. The groups were then able to compare ideas in a co-ed setting, where interest level among BOTH sexes remained equal throughout the lessons. As a result, we found that using the same curriculum with gender-specific groups may be the most beneficial means of conducting the STEM program at the BGCW.

Finding 6: The teacher-student relationship is crucial in a STEM classroom in order to expose students to positive role models and create a comfortable learning environment

Dr. Harmon Hines and Donata Martin highly recommended that the teacher of the pilot program at the BGCW must build relationships with the students in order to promote a comfortable learning environment. Many of the STEM professionals we spoke with defined ‘comfortable learning environments’ as places where students are willing to express their thoughts and ideas, as well as safely approach the scientific method through success and failures. To provide this for urban and underrepresented youth, the teacher must act as a role model/mentor to give the students an exemplar. Dr. Harmon Hines and Mr. Layne, active members in the Worcester Public schooling systems, stressed the reality that a majority of urban youth does not have role models outside of school to guide their actions and teach them how to act appropriately in different settings. Therefore, it is important that the teacher act in a manner that will raise the children up. For example, the teacher should use proper grammar when speaking with the children and enforce positive behavior in the classroom. If the teacher acts as a friend to his/her students, the students will think it is acceptable to use inappropriate actions and language in a classroom environment due to the lack of authority. A 2012 report of the BGCW indicates that 64 percent of the 130 young attendees are living in a single parent home (Foundation for the Future, 2013), and thus these students lack an authoritative figure at home. Therefore, our finding came from the experience of many STEM professionals and advocates in the urban youth setting, that the importance of having a teacher-student relationship is more than necessary, but also plays a crucial role student’s exposure and understanding of STEM education.

At the Massachusetts STEM Summit 2015, we attended a session entitled *Breaking Down Barriers: Social and Cultural Contributors to Ensure STEM for All,* a panel discussion given by STEM professionals that provided insight on student and teacher relations. According to Connie Chow, a Board Member of the Massachusetts Academy of Sciences, an influential mentor should have three important qualities to help expose students to a comfortable learning environment. First, the mentor should be close in age to the students, creating a comfortable and relatable atmosphere. Second, the mentor should look like the student and should come from a similar area. Finally, the mentor must build a teacher/student relationship based on trust and comfort. In a case study presented in this session entitled *Math is for Girls,* a female high school student who fails her freshman math class attends a math program held at UMass Amherst. The teacher of the program is an African American college sophomore student, but because the teacher is close in age to the student, shares similar interest with the student, and grew up in the same city, the student found the program more enjoyable. It was in the student's ability to connect and relate to a successful and influential member of the STEM fields that it became relevant and worth-while. This case study illustrates the importance of exposing students to positive role models and creating a comfortable classroom setting. Also, this study shows that a positive role model can influence the way that minorities can picture themselves in the STEM fields. Students will gain confidence and motivation to acquire a STEM job if they can see that it is obtainable by role models of similar ethnicities, gender, and backgrounds. Lauren Monroe, Co-Founder and Director of Worcester's Think Tank, described teacher modeling as an important aspect of STEM programs. She described a "great" teacher as a teacher that can successfully engage a classroom as well as read a classroom through an assessment of the children and their emotions. Also, a "great" teacher always knows if certain children are struggling and who to work with in depth in a subtle way. According to Dr. Deborah Harmon Hines, if a teacher points out a child's weaknesses in front of his/her peers, that child will lose face meaning that they will no longer actively engage in a program due to a loss of self-worth and embarrassment. Lauren Monroe also emphasized the idea that girls flourish with the presence of female teachers because, with only male teachers, there may be a lack of advocating for girls, which may lead to girls not asking for help or approaching a male teacher. Thus in a co-ed environment, ideally, both a male and female teacher should be leading the classroom. To create a comfortable learning environment where the students are able to engage in their work without any distractions, it is necessary that there is an authoritative role model in the classroom. For example, in one of the pilot sessions that we conducted, one child misbehaved and slowed down the entire class. Mr. Aponte pulled the child aside, and explained to him that if he did not properly behave, he could not take part in the activity. Surprisingly, the child's behavior drastically improved, allowing his peers to focus on their work. Tricia Desmarais explained that having a mentor that is less involved in teaching the lesson, but more focused on the student integration and understanding of the lesson, is necessary in a classroom. This is because it provides students who may be struggling with their work or misbehaving, to have an authoritative figure to talk with in a comfortable setting. The mentor will provide the children with the attention they need, while making them feel important.

Finding 7: Flexibility allows for a strong program

During the pilot sessions, we learned that particular lessons may not play out exactly as anticipated. For example, an activity that we planned to last 45 minutes only lasted about 25 minutes. As a result, we had to be creative enough with the material to fill the rest of time and maintain enthusiasm. Following the session, we received praise for our flexibility from our sponsor Tomas Aponte, who had sat in on the session with us. This event led to our finding that flexibility gives rise to a strong program.

Flexibility helps when encountering unexpected occurrences. If an activity ends quicker than expected, such adaptability can help fill the dead space. Additionally, it helps to maintain engagement and prevents the kids involved from getting bored. Our sponsors expressed the flexible style of their current programs, which allow the instructor to design lessons based on the day or student's activity level (J. Fowling, personal communication, November 5, 2015). Therefore, we felt adding this flexible component to the curriculum would benefit the Club. Sometimes unanticipated events happen, but a flexible program can compensate for these occurrences and carry on without losing the students' interest.

4.2 Perceptions of and Level of Interest in STEM Among Youth at the BGCW

After speaking with numerous STEM advocates and professionals in the Worcester area, we targeted our focus towards the children and members of the Boys & Girls Club. Through a series of informal interviews with ours sponsors and small focus group discussions with the children, we began to establish specific findings relative to the perceptions and level of interest in the STEM topics within the 10-13 year old members at the BGCW. We were able to synthesize three findings under collective topic of *Perceptions of and Level of Interest in STEM* among the urban youth at the BGCW.

Finding 8: Many 10-13 year olds at the BGCW may have interest in the STEM disciplines however often do not have the opportunities for this to be discovered

Through focus groups and individual discussions with the 10-13 year old students at the BGCW, we found that many students at the BGCW have interest in STEM disciplines as possible careers to pursue. At this point in their education process, students have mainly experienced the STEM subjects in traditional schooling in the form of science and math lessons, which are primarily test-based and lack the hands-on, experiential learning styles, which often characterize successful STEM education. Due to the the less engaging style of the traditional classroom, students may have interest in the fields of science, technology, engineering, and math, but do not particularly enjoy how these subjects are taught in school. Our focus groups supported this where students were asked to rank 10 careers on a scale of 1 to 10, from least interesting to most interesting. In the first round, these jobs were represented solely by their names printed on a white piece of paper. In the second round, pictures represented the jobs and we noted a 16 percent increase in the ranking of STEM jobs.

Therefore, we concluded that the students in the focus group are interested in the actions that STEM professionals do on their job, however the students' preconceptions or previous experiences may affect their views of the STEM professions. Additionally, when speaking with students about their favorite and least favorite subjects in school, multiple students said they find interest in their science and math classes, but dislike the teacher or their teacher's way of teaching. The responses and feedback we received about their classroom instructors coincide with finding 6, and the importance of the teacher in the STEM environment. In focus groups, students expressed their overwhelming desire to participate in science/math related activities because they are readily restricted within the classroom. We were able to speak with seven children individually that had expressed interest in STEM during the focus group, and more than half expanded on their opinion by discussing the role of their teacher. The students that wanted to pursue STEM topics or found overt interest in them expressed their admiration and respect for their instructor. Contrastingly, three students expressed that their interest in science/math is hindered because of their dislike in teaching style or their teacher in general. In consulting our notes from the discussion, we came to realize that children at the BGCW expressed current interest in the STEM disciplines, but we found that the interest level is restricted by classroom availability and teaching style. Overall, we have found that interest in the STEM disciplines exist among 10-13 year olds at the BGCW, but is hindered by external influences such as disinterest in STEM teachers or lack of classroom hands-on learning activities.

Finding 9: Interest in STEM disciplines among 10-13 year olds at the BGCW is dictated by exposure to related careers and financial awareness

In order to collect information about the level of exposure and interest in STEM among the 10 to 13 year olds at the BGCW we held small focus groups with the student members of the Club to hear their specific opinions. It became evident that when asking the students what STEM disciplines they found most interesting, their level of exposure of STEM often determined their feedback and responses. This means that we found students had higher interest in STEM jobs when they could identify examples, for instance, “Bill Gates was a software developer, and if I am one like him I will be a billionaire too”. These anecdotal stories were repeated often during our focus group sessions, and it became clear that the understanding students had of a STEM profession was based on their previous level of exposure. For example, some of the students have relatives who are are doctors and engineers, and these students seemed to have an increased interest in STEM. Even students who were unable to make a connection to a known STEM professional, were still aware of the amount of schooling and possible salary of certain STEM careers. For instance, many students discussed the position of doctor as a well-paying career, but one which takes multiple years of schooling. Additionally, we noticed that the careers that students perceived to be high paying had an increased interest by the students, whether or not these jobs were in the STEM fields. This means that the students may have an increased financial awareness due to their economic situations and may have been guided towards careers or interests which may pay off better in the future. By watching the weighing of pro’s and con’s among the children, we found that the interest level and desire of the STEM jobs among the children is often dictated by their exposure to STEM careers and their possible need for financial stability.

Finding 10: Children's cultural and economic backgrounds may affect perceptions of how STEM applies to them

Throughout our numerous interviews and archival research, we asked STEM professionals and advocates for their opinions and advice on ways to implement a STEM program for urban youth at the Boys & Girls Club of Worcester. However, it was not until speaking with members and staff of the BGCW that we recognized the important role of the cultural and economic backgrounds of the children. The cultural and economic backgrounds of the children expand beyond the financial awareness mentioned in Finding 9. In speaking with our sponsors, Joanne Fowling and Tomas Aponte, they explained that due to the ethno-diverse community of members, it is realistic that the perceptions surrounding STEM, and how STEM applies to the students, vary on an individual basis. Ms. Fowling went on to discuss the cultural backgrounds of BGCW students relative to possible influences connected to their cultural backgrounds (J. Fowling, personal communication, November 26, 2015). We found that through influence of parents' desire for a specific career or cultural demands to succeed, children's interest level may be inhibited. We understood that children with the BGCW came from different and diverse backgrounds, but underestimated the influence cultural and economic factors may play. By considering each students cultural and economic background, we found that their perceptions of STEM relative to their own abilities or opportunities to succeed are hindered.

From this discussion, we were able to notice that in the focus groups with the children, the student's individual situations may impact their perceptions of STEM. The interest that certain students currently have in STEM professions may be a result of parental influence or other cultural factors that may subconsciously play a role. For example, Ms. Fowling explained that some of her students with cultural traces in the Caribbean Islands likely have parental influence to pursue the athletic outlets at the Club such as their successful Boxing program. Other students during individual discussions verbally indicated that they *must* follow in the footsteps of their parents and pursue similar job fields-- supporting our finding that the children are influenced by personal cultural/economic factors. With that said, other students that find interest in STEM, or want to become a STEM professional, may be aware of the financial constraints of their family, limiting their ability to attend college. In order to bridge the gaps between those students who might have familial or societal encouragement to pursue STEM and those who may not have any such motivation, we have made recommendations to better enable urban or minority youth to envision themselves in STEM careers.

4.3 Program Recommendations

Following the acquisition of our findings, we wanted to offer our own recommendations for the progression and sustainability of the program. We believe these recommendations will be sufficient in enhancing the quality of the program for the Boys & Girls Club of Worcester (BGCW).

Recommendation 1: Incorporate hand-on, problem-based learning

We recommend that after school or out-of-school STEM integration programs involve some aspect of experiential, hands-on learning. This means that instructors include portions of the curriculum that involve students manipulating and tinkering with lessons and STEM concepts. Problem-based learning, or activities center around a common goal/solution, should be incorporated when possible into the curriculum in order to allow students to make connection to real-world problems, as well as grasping concepts through application. We were able to do this in the materials we developed by providing students with example scenarios such as “We must create a mode of transportation to get across Lake Quinsigamond", and conversations about STEM professionals tackling these tasks add supplemental understanding.

Recommendation 2: Assess program through pre- and post- evaluations

In order to assess the student's improvement and the program's success, we recommend that pre- and post-tests be performed as a way of program evaluation. This means that at the beginning of the program students are provided with a simple survey that is then repeated at the completion of the program. This can be a simple form of evaluation that may be supported through lesson discussions that act as the evaluation of that day. It is necessary to relieve the "test" atmosphere from out-of-school programs; therefore, pre and post assessments are not necessary for each individual lesson. In addition, the BGCW performs pre-and post- evaluations regularly with their programs, which ensures that this form of evaluation will work best at the Club. A sample pre-and post-test that we administered in the piloted program can be found in Appendix G. Even though each student only participated in two pilot sessions, these evaluations proved useful in measuring the effectiveness of the sessions.

Recommendation 3: Separate genders but utilize the same curriculum

We learned that STEM educators have conflicting thoughts regarding gender separation when implementing a STEM program (Finding 5). While some interviewees thought that boys and girls should be taught separately with different curriculums, others pushed for teaching boys and girls together.

As mentioned in Finding 5, we found through the pilot sessions that gender-specific groups may work best for the BGCW. The kids are already used to gender-specific programming as boys and girls are separated in many programs at the BGCW. Therefore, separating boys and girls for a STEM program will be an easy transition for the staff and the members.

As a result, we recommend that boys and girls be taught separately, but also that they be taught the same curriculum. This arrangement ultimately will contribute to the success of the program and the students. The separation removes distractions associated with the opposite sex that kids of the 10-13 age groups may experience. Additionally, since girls may hesitate to participate in a co-ed environment and boys may push to lead, the gender division works to allow equal participation among the sexes in a safe and comfortable environment.

Though we recommend that the boys and girls are split up in the new Boys & Girls Club STEM program, it is important that they are taught the same curriculum. Doing so ensures that both groups take away the same skillset from the program, and gender stereotypes are not reinforced by dictating certain gender-specific content. Each group conducts the same learning activities and the boys and girls are equally exposed to STEM. As a result, for this STEM program the boys and girls ought to be separated but should follow the same curriculum. Students can then be brought together in smaller sessions to perform competitions or social interaction activities.

Recommendation 4: Have program graduates return as mentors

We recommend that, to ensure comfort, familiarity, and growth within the classroom, students should return as peer mentors to teach the other students after completing the program. Since the Boys & Girls Club provides services for children up to the age of 18, it would be possible for students to return as a counselor or mentor for the younger students in the program. This would ensure longevity of the program because alumni would contribute to its sustainability, and younger students who are familiar with the mentor will be able to thrive in a comfortable learning environment. This recommendation could be beneficial for all parties involved because volunteers are easily accessible with the Club, leadership opportunities empower student members, and current program students could work with someone with whom they can easily relate. Since the club currently promotes leadership opportunities, we feel that peer mentors would provide familiarity and sustainability within the program.

Recommendation 5: Utilize field trips and relevant STEM professionals to increase exposure

In order to increase exposure to STEM professionals and disciplines beyond the classroom, we recommend that instructors provide students with a makeshift portfolio, tailored to the STEM interest of each child. This means that during the middle or latter half of the program, teachers would ask students where their interest currently lies in the STEM fields (ex: engineer, architecture, physics, chemistry, aerospace, etc.), and the teacher can provide the student with a simple summary of what the job does. However, to help students relate to it, we suggest that the selected STEM professionals should be similar to the children in several ways. For example, the portfolios we have provided for the students in the program at the BGCW are comprised of either Boys & Girls Club alumni, or successful STEM professionals that were born and raised in Worcester, Massachusetts. As a result, students are able to connect with a successful person in the STEM field that intrigues them, as well as learn more about a person who grew up in the same city as they did or is affiliated with the Boys & Girls Club of America. Another way to increase this exposure would be to implement small field trips or trips to makerspaces in order to provide students with the necessary exposure and understanding of the possibilities the STEM disciplines offer. For example, field trips to Technocopia or to the Ecotarium, both located in Worcester, MA, would be sufficient in increasing the children's exposure to the STEM fields.

Recommendation 6: The instructor should be well-qualified to lead an adaptable program

Since we will not be the ones leading this program, we recommend that the Boys & Girls Club of Worcester find a well-qualified, experienced instructor who has a background in STEM. Since the program itself was built to be flexible, an experienced instructor will be able to read the room and decide how best to conduct the specific activities. For example, we intended some activities as group projects and, while teamwork is a key component of the curriculum, some activities might work better as an individual exercise based on a certain student's needs. In that respect, the instructor should be aware of how to use the flexibility of the program to his or her advantage.

Additionally, the instructor should have a background in STEM. Such a quality will work twofold as the instructor will be able to grasp the material easily and teach it effectively, and the students will get deeper insight into STEM from an instructor who is familiar with the field. Having a background in STEM also plays into the flexibility of the program. For example, as students from WPI, we have a background in the STEM subjects, and when leading the pilot sessions, one of the boys asked how math could be used in a particular activity. While math was not initially part of the lesson, group member Michael Sullivan, an actuarial mathematics major, was able to incorporate a mathematical component for the student. Therefore, an instructor with a STEM background can build on the flexibility of the program by being able to utilize his or her knowledge to answer any unexpected questions the kids may ask.

Ultimately, a well-qualified instructor with a STEM background will enhance the quality of the program as well as enhance the quality of the students' learning experiences.

Chapter 5: DELIVERABLES

This chapter comprises a brief description of the results and deliverables from our project. We discuss the learning outcomes of the STEM program for the Boys & Girls Club of Worcester, as well as the curricular design.

5.1 Learning Outcomes

In the collection of our findings, we create a set of four learning outcomes to provide a structure for our second deliverable, the 7-week core STEM curriculum. To coincide with our third objective – to determine appropriate and feasible learning outcomes – we consulted various STEM professionals, existing outcomes of successful STEM programs, and the input of our sponsors. Using this information, we tailored the learning outcomes of the program BGCW members and interwove the overall goals and hopes of our sponsors into these outcomes. The list of learning outcomes is provided below:

1. Increase engagement, interest, and positive attitudes towards STEM
2. Children are able to apply STEM principles through hands-on learning (outside of the classroom)
3. Children develop a greater understanding of the breadth of STEM fields and their abilities to attain such opportunities
4. Students reinforce concepts set by the Massachusetts Common Core and Next Generation Science Standards

The main hope is that children involved will engage in STEM activities that will boost interest and positive attitudes towards the growing STEM fields. This coincides with Finding 8, which states that children at the BGCW have current interest in STEM. The first learning outcome also takes into consideration Findings 9 and 10, as they discuss the interest of STEM relative to the BGCW members' socioeconomic or cultural backgrounds. Additionally, through hands-on application, the students will grasp STEM principles outside of the classroom as well as develop a greater understanding of the breadth of STEM disciplines. Through our understanding of Findings 1 and 2, we structured the second learning outcome to ensure that the program provides activities and opportunities for the youth to apply what they have learned relative to the STEM topics. To support both the first and second learning outcomes, we recommended that the STEM program utilize a hands-on, experiential learning structure. This will provide an atmosphere where the students may experience the STEM disciplines. Furthermore, the program will also contain a learning outcome to coincide with the students' classroom content. This outcome supports Findings 2 and 4, that not only do urban youth respond well to relatable topics, but also that their socioeconomic background does not determine their academic capabilities. In order to do so, we recommended that the lessons mirror the learning standards set by the Massachusetts Common Core and Next Generation Science Standards. By matching the learning outcomes to specific findings, we were able to create recommendations for the program and provide a suitable curricular design. Ultimately, these learning outcomes serve to spark interest and educate the middle school students involve in the program.

With the learning outcomes in mind, we began to design a curriculum that would cater to the hopes and goals of our sponsors. We began to lay the structure of the program including the target audience and resources available and have displayed this information in Table 2 below.

Program Layout	
Goal:	To develop and implement a hands-on STEM education program that focuses on increasing student appreciation and positive attitudes towards STEM, and promote an understanding of the depth of STEM fields.
Duration of Program:	7-Week Curriculum Bolstered by smaller backup units (Permits flexibility)
Target Audience:	The curriculum mirrors Common Core and Next Generation Science Standards relative to middle school aged students. Year 5 through 8 students (age 10 to 13)
Deliverables:	• Instructor's manual which includes a detailed curriculum lesson plan and any necessary teacher/student review sheets • Resources for exposure: field trip possibilities, communities

	connections, and unique STEM portfolios
Learning Outcomes:	1. Increase engagement, interest, and positive attitudes towards STEM 2. Children are able to apply STEM principles through hands-on learning (outside of the classroom) 3. Children develop a greater understanding of the breadth of STEM fields and their abilities to attain such opportunities 4. Students reinforce concepts set by the Massachusetts Common Core and Next Gen. Science Standards
Structure of Sessions:	Each hybrid lesson consists of one or more ways to associate discussion with varying STEM professions. Students participate in lessons involving both group and individual work. Upon completion of the program students will have participated in activities involving one or more of the STEM disciplines. • Introduction discussion • Hands-on activity • Closing discussion
Activities Involved:	• Hands-on, experiential learning activities • Student reflection through worksheets • Analysis/discussion of findings • Take home assignments or further research

Table 2: Layout of the curriculum and its involved components

5.2 The Curriculum for the Program

After determining the layout of the program, we built specific lessons for each session. As we designed the curriculum, we made sure that each session covers one or more learning outcomes. Coinciding with Finding 3, each session has its own subject with activities that are thematically connected to one another. Additionally, the concepts of each session build off one another so that the students may apply knowledge from previous lessons to future activities. The concepts are also in line with MA Common Core/Next Generation Science Standards to relate what the kids learn in this program to the ideas they are learning in the classroom.

To ensure the program's effectiveness, we chose hands-on, engaging activities that would allow the students to learn and think about new concepts while completing their work. Almost all of the sessions include at least two lessons. We also included lesson extensions and back-up units to allow for flexibility within the program thereby catering the curriculum to Finding 7 and

Recommendation 6. We have displayed a summary of the curriculum in Table 3 below.

Additionally, the full curriculum has been included in Appendix G.

Unit Title	Lesson Title
Unit 1: Intro to STEM	Skewer Through a Balloon
	Seven Layers Density Column
	Pop Rocks Experiment (Optional)
Unit 2: Activities in Motion	Hovercraft Racers
	Balloon Launcher
Unit 3: Activities in Engineering	Marshmallow Design Challenge
	Bridge Building
Unit 4: Activities in Sound	Introduction to Sounds and Pitches
	Build a Band
Unit 5: Gravity and Forces	Egg Drop
Unit 6: Circuits	Flashlight Dissection
	Chibitronics
Unit 7: Party Science	Skewer Through a Balloon
	Make Your Own Ice Cream
Back-up Units	Spacecraft on Mars
	Make Your Own Watercraft

Table 3: Curricular Structure

Chapter 6: CONCLUSION

At the end of our time with the Boys & Girls Club of Worcester (BGCW), we produced the curriculum for a STEM program. This curriculum is representative of the main goal of this project: to develop a program that would generate interest in STEM among the 10-13 year old kids at the Boys & Girls Club of Worcester. The curriculum also represents a synthesis of concepts that stemmed from research contained in existing literature, the ideas of STEM educators in the Worcester area, and our own creativity. Each experience equipped us with the necessary tools to build a successful STEM program. We are confident in the curriculum and believe that its implementation will be a success with the Boys & Girls Club of Worcester.

After fifteen weeks of work, we collected copious amounts of data through research, a series of interviews, focus groups, and pilot sessions. Each event granted further insight into the outcomes of our project. As we followed the steps laid out in the methodology, we yielded important information and accumulated several significant findings. Each finding allowed us to make proper refinements to the curriculum thereby making a solid program catered to the children at the BGCW.

The STEM fields are growing nationwide. However, as these fields grow, there remains a dearth of individuals pursuing STEM careers, and women and minorities in particular remain underrepresented. With this project, however, we believe the program can inspire the urban youth in Worcester to pursue science, technology, engineering, and math in the future. These children will not only learn the benefits of a STEM career, but also that STEM is an exciting field. This program will ultimately make a difference at the Boys & Girls Club of Worcester and set the kids involved on a path towards a successful future.

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APPENDICES

Appendix A: Methodology timeline

	Weeks						
	1	2	3	4	5	6	7
Meta-analysis of existing STEM programs							
Conduct interviews with STEM advocates							
Build curriculum based on given information							
Hold focus groups with kids at the BGCW							
Implement pilot sessions of STEM program							
Make refinements to program							
Recommend final design of the STEM program							

Appendix B: Interview information

<u>Interview Preamble:</u>

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews to learn more about existing STEM programs at the Boys & Girls Club and best practices when teaching STEM. We believe this kind of research will ultimately give us insight into the best STEM curriculum to develop for implementation at the BGCW. Your participation in this interview is completely voluntary and you may stop the interview at any time.

Please remember that your responses from this interview may remain confidential. No names or identifying information will appear in any of the project reports or publications without your permission. This is a collaborative project between the BGCW and WPI, and your participation is greatly appreciated. If interested, a collection of our results can be provided at the conclusion of the study.

Interview questions for Lauren Monroe:

1. What was your motivation for this project?
    a. Where did you start…
2. What was the evolution of it?
    a. What were your first STEM workshops in the program?
3. We understand you hold two separate programs...what are major differences between your daytime and afterschool sessions?
    a. Are the curriculums structured differently?
4. What are some best strategies for keeping kids interested in STEM/STEAM that you've seen?
    a. For middle school students in particular?
    b. What is the ideal number of students for each of your class and **why?**
5. What strategies haven't worked in getting kids interested?
    a. Tactics used to reign in attention?
6. Where do you pull your instructors from?
    a. Do you hold any training sessions or orientations for those volunteers?
    b. What is the structure of these orientations?
7. How do you choose your curriculums/activities?
    a. Where do ideas for curriculum/activities come from?

    b. How do you do this with kids not brought up in the STEM system?
8. How do you obtain your resources?
    a. We heard about Technocopia Worcester…how are you affiliated?
    b. Can you recommend resources for non for profit companies? Possible grants?
9. In your experience, what are the most important qualities for a successful STEM program?
    a. Learning outcomes?
10. If we have any additional questions later on in our project, can we follow up with an email?
11. Are there any other organizations similar to yours which may assist us in our research for our project?

Interview questions for Donata Martin:

1. Can you give some background on the STEM offerings at the BGCFL?
2. How did the BGCFL begin its focus on STEM?
    a. When did you initiate STEM education?
    b. What was the driving force behind the initiative?
3. Which programs are the most popular? Why?
4. Where does the teaching staff for these programs come from?
    a. Are they volunteers?
5. What are some best practices when engaging kids in STEM?
    a. What strategies work well?
    b. What strategies do not work well?
6. How do you assess the success of the programs?
7. How do you ensure the sustainability of these programs?
    a. Students returning, teaching/mentoring processes, resources, budget
8. What are the learning outcomes of your STEM programs, and how does this reinforce traditional classroom content?
9. Do the lessons change constantly or are they projects that last over the course of a few days or weeks?
10. What are some resources you can suggest for our curriculum?
11. Where do your funds come from? What funding opportunities can you suggest for our program?
12. Can you recommend anyone else that we might speak to who could offer us
    a. Can you offer insight in the development of the BGCW STEM program?
13. Do you mind if we contact you if we have any additional questions?

Interview questions for Martha Cyr:

1. How did you get involved with the K-12 STEM Outreach Program at WPI?
2. Can you tell us a little more about your role in the STEM Outreach Program?
    a. We understand that you focus on making sure that K-12 teachers and education leaders are well prepared to implement STEM curriculum in schools
    b. How do you determine if a teacher/education leader is well prepared to teach STEM?

3. Can you tell us more about the programs that provide training and classroom resources for teachers?
    a. We understand that you helped develop TeachEngineering, an online resource for K-12 engineering educators. Can you tell us a bit about your involvement with this program?
4. What are some of the programs that you have overseen locally or here on campus?
    a. What was the feedback? From participants, volunteers, teachers?
    b. Strength and weaknesses of these programs
    c. What are the learning outcomes?
5. In your experience, what are the most important qualities for a successful STEM program?
6. Can you recommend any resources that we might review as we continue our research?
7. Do you have any suggestions of funding opportunities we may be able to look into for the BGCW, as funding may be within the scope of our project?
8. Can you recommend anyone else that we might speak to who could offer us
    a. insights in the development of the BGCW STEM program?
9. Do you mind if we contact you if we have any additional questions?

Interview questions for Shari Weaver:

1. How did you get involved with the STEM outreach program at WPI?
    a. We saw from your bio you work K-12 outreach; can you explain more at what level you are involved?
2. Can you tell us a little bit about what you do?
    a. We understand you work with faculty as well as parents of students as well
3. What tactics do you stress to faculty in STEM integration?
4. What are some of the programs you have overseen here on campus or locally?
    a. Tell us more about those…
    b. What was the feedback?
5. What were the strengths and weakness of these programs?
6. We understand you work with grants for STEM programs, how are you involved with these?
    a. We understand our organization is non for profit and they may need assistance...
7. How do you recommend certain programs? and what kind of students usually attend such programs?
    a. Do you have any interaction or outreach programs involve minorities and
        i. women in STEM?
8. Do you know of any strong STEM programs geared towards middle school students? Underprivileged students?
9. Do you have any contact information for us or available resource information?

Interview questions for Deborah Harmon Hines and Robert Layne:

1. What sparked your interest and passion in STEM education?
2. We understand you worked with medical students initially, what motivated you to extend the reach of your programs to younger aged students?

3. How and where did you get involved in the Worcester community specifically?
4. Do you have any recommendations for teaching STEM based programs in urban youth? Have you noticed any differences?
5. How are your programs designed?
    a. What are tactics and techniques you have used to integrate STEM in the urban setting?
6. We will be working with 10-13 year olds, what have you noticed works best for integrating STEM to this age group?
7. When you conduct programs in the community, what are the learning outcomes or takeaways that you hope the children leave with?
8. Do you play a role in the specific activities or curriculums involved in the STEM programs?
9. How do you determine the success of these programs?
    a. We understand that children have high success rates from programs you have ran, what have you found keeps a structured learning environment?
10. What are any obstacles you have faced?
    a. We understand sometimes a lack of role model or parental influence may hinder children in STEM education, have you seen this in your own experience?
11. As a woman in STEM, what is your perspective on any gaps and barriers present in STEM education?
    a. Has this played a role in your own experience?
    b. What are possible ways of working through this?
12. Do you have any further advice guidance that may help us in our program development process?
13. Can you recommend any resources that we might review as we continue our research?
14. Can you recommend anyone else that we might be able to speak to who could offer us insights in the development of the BGCW STEM program?
15. If we have any additional questions, do you mind if we contact you?

Interview questions for Elisa Heinricher:

1. So to begin, why don't you give us some background information on your involvement in robotics here at Bancroft.
2. Why did you feel it important to implement a robotics program in both the high school and middle school?
    a. Why did you select robotics and not another STEM subject such as an engineering club for example?
3. How did you gage need or demand?
4. How did you measure the initial level of interest/popularity?
5. Can you tell us about the students involved in this program? (gender of the students, are they already interested? Were they already previously educated in the subject?)
6. Once up and running what was the evolution of the program? What came along after implementing?
7. What obstacles did you or do you currently face?
    a. In funding? In gaining interest? In engagement?

8. We understand the demographics of students at Bancroft tend to be more affluent. Given that the BGCW serves a different socio-economic demographic, what are some challenges you may see us facing in implementing a STEM after-school program?
    a. We know there is little funding for our program so we expect accumulating resources to be a challenge we face… do you have any low-cost STEM curricular suggestions?
9. How did/do you evaluate the success of this program?
10. How do you maintain interest in the program as children graduate?
11. How do you generate interest within the middle school?
12. What are the learning outcomes of the middle school robotics program? What do you hope each child gains from participating in the program?
    a. How does classroom content support these outcomes?
13. Our target age range is 10-13 years old, from your experience, what are common themes or techniques you have used in STEM implementation with this age range?
14. Do you have any further advice guidance that may help us in our program development process?
15. Can you recommend any resources that we might review as we continue our research?
16. Can you recommend anyone else that we might be able to speak to who could offer us insights in the development of the BGCW STEM program?
17. If we have any additional questions, do you mind if we contact you?

Interview questions for Tricia Desmarais:

1. Can you tell us a little about Camp Invention?
    a. Discuss the demographics of the participants (age range, ethnicity, male-to-female ratio, etc.)
    b. Talk about the activities the kids participated in.
2. How did you get involved with Camp Invention?
3. Can you discuss the strengths and weaknesses of Camp Invention?
4. What strategies have you found work best when engaging kids in STEM?
5. Do gender and race affect the outcomes of the different applied teaching strategies?
6. How did you keep the kids engaged during a time they may not otherwise be focused on academics?
7. Can you suggest any resources we should look at when building the program for the BGCW?
8. Do you have any further advice for us as we begin building a STEM curriculum?
9. Funding may be an item within the scope of our project; do you have any suggestions of funding opportunities we may be able to look into for the BGCW?
10. Can you suggest any other contacts that may be relevant?

Appendix C: Focus group information

<u>Focus Group Preamble:</u>

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews to learn more about your thoughts on STEM and level of interest in STEM. We believe this kind of research will ultimately give us insight into the best STEM curriculum to develop for implementation at the BGCW. Your participation in this focus group is completely voluntary and you may stop the interview at any time.

Please remember that your responses from this interview may remain confidential. No names or identifying information will appear in any of the project reports or publications without your permission. This is a collaborative project between the BGCW and WPI, and your participation is greatly appreciated. If interested, a collection of our results can be provided at the conclusion of the study.

Focus group discussion topics:

- Do you know anyone (personally) who is in the STEM field?
- Is anyone in your family a scientist or mathematician?
- What is favorite subject in school?
- What is your least favorite?
- Who can tell me what they think an engineer does?
- What clubs do you participate in here?
- Thinking about it, what would you like to be when you group up?

Appendix D: Sources used for building the curriculum

1. PBS Design Squad Parent Educator Resources
   a. http://pbskids.org/designsquad/parentseducators/lesson-plans/electricity_and_circuits.html

2. EGFI Teacher Resources (sponsored by American Society for Engineering Education)
   a. http://teachers.egfi-k12.org/

3. Steve Spangler Science
   a. http://www.stevespanglerscience.com/lab/experiments/

4. DIY STEM 2.0 curriculum (for the Boys & Girls Clubs of America)
   a. Time Warner Cable. (2015). *DIY STEM 2.0: The Science of Every Day for Boys & Girls Clubs Members 9-12*. Boys & Girls Clubs of America.

5. STEM to Story: Enthralling and Effective Lesson Plans for Grades 5-8
   a. 826 National. (2015). *STEM to Story: Enthralling and Effective Lesson Plans for Grades 5-8* (J. Traig, Ed.). Jossey-Bass.

6. STEM After School: How to Design and Run Great Programs and Activities
   a. http://expandedschools.org/sites/default/files/STEM_Guidebook_Update2014.pdf

7. The Concord Consortium Middle School Curriculum
   a. http://concord.org/stem-resources/grade-level/middle-school

8. McGraw Hill Education Resources (provided sign-in information from attending the Massachusetts STEM Summit Conference)
   a. http://media2.k12.mhedu.com/

9. Engineering is Elementary (developed by the Boston Museum of Science)
   a. http://eie.org/engineering-everywhere/curriculum-units

10. Teach Engineering: Curriculum for K-12 Teachers
    a. https://www.teachengineering.org/browse_curricularunits.php

11. Chibitronics resource website
    a. http://store.chibitronics.com/collections/all

Appendix E: Assessment of classroom

<u>Note structure for assessing classroom engagement</u>

Student engagement can be defined in a meta-analytical way. Engagement includes behavioral, emotional, and cognitive concepts. Notes taken from observations enhance understanding of the context and are best done in small classroom settings. The major indicators for determining whether students are engaged are as follows:

1. Alert, tracking with their eyes, and paying attention
2. Asking content-related questions and answering questions
3. Students are exploring, solving problems, explaining, and evaluating
4. Students sustain involvement in activities with positive emotional tones
5. Students exert effort and concentration in learning tasks

<u>Affective behavior (interest, attitudes, appreciation, and emotion)</u>

- Being 'self-regulated' – approaching tasks with confidence, diligence, and resourcefulness

- Self-regulated learners:
    - Plan
    - Set goals
    - Organize
    - Self-monitor and self-evaluate during the learning process
    - Monitor their own strategies and make modifications
    - Self-control

- Positive emotional engagement
    - This allows students to make connections with the institution and influence their willingness to perform tasks

<u>Cognitive behavior (recall and recognition of knowledge, developing intellectual skills)</u>

*Anderson and Krathwohl's Taxonomy of Cognitive Behavior

- Being thoughtful, strategic, and willing in the exertion of effort to comprehend complex topics and master skills

- Making connections to what they are learning and to what they have previously learned

- Remembering – being able to recall knowledge (from memory) to produce facts or retrieve information

- Understanding – constructing meaning from functions like interpreting, classifying, summarizing, and explaining

- Applying – carrying out and using procedure through implementing and applying learning to models and simulations

- Analyzing – determine how parts relate to each other or connect in an overall structure; mental functions are organizing, attributing, and being able to distinguish (students can show a graphic representation)

- Evaluating – making judgements based on checking and critiquing

- Creating – being able to put elements together to function as a whole

<u>Physical behavior (physical time spent working on a task)</u>

- Students show positive emotions during ongoing action
    - Enthusiasm, curiosity, optimism, and interest

- Students initiate action if they are given the opportunity to do so

- Disengagement versus persistence in their level of work

- Students display social engagement with peers; teamwork

<u>Signs of engaged learners</u>

1. Students are on time

2. Students complete assignments/tasks

3. Students participate positively in activities
    a. Positive communication (asking questions)
    b. Positive use of resources
    c. Positive emotional tone

4. Students can make corrections in their own work

5. Observe:
    a. Asking/answering questions
    b. Participating in classroom tasks

c. Talking about the subject

6 C's of the classroom

- Competence – positive view of one's actions in specific academic areas, including social and academic skills

- Confidence – a sense of overall positive self-worth and self-efficacy

- Connection – positive bonds with peers and instructors that are reflected in engagement and contribution

- Character – respect for academic, cultural, and social norms; possess appropriate behavior (sense of right and wrong)

- Caring – sympathy and empathy for others

- Contribution – support to a greater community

Appendix F: Parental consent forms for focus groups and pilot sessions

Consent form for focus groups and photo/video participation:

Due: Friday, November 13, 2015 to Tomas Aponte
Free Boys & Girls Club calendar for those who return the form in on time

Participation Consent Form

We are a group of students from Worcester Polytechnic Institute (WPI) in Massachusetts who are currently working on our Interactive Qualifying Project, which is a project usually done during Junior year. The goal of our project is to design a Science, Technology, Engineering, and Math (STEM) curriculum for the Boys & Girls Club of Worcester. The hope is that the final program will engage students by increasing interest and exposure to the STEM disciplines through hands-on learning. Through real world application and experimentation, the children will perform activities based on science, technology, engineering, and math fundamentals through teamwork, brainstorming, and creative problem solving.

Before implementation, we are conducting focus group discussions with Club members and volunteers to learn more about the dynamic at the Boys & Girls Club to gain insight to the student's views of STEM. This kind of research will ultimately give us insight into the best STEM curriculum to develop for implementation at the BGCW. Your child's participation in the group discussions is completely voluntary and the responses from this discussion will remain confidential. No names or identifying information will appear in any of the project reports or publications without your explicit permission. This is a collaborative project between the BGCW and WPI, and your child's participation is greatly appreciated.

We will also be conducting pilot sessions including sample activities and lesson plans. Your permission will allow your child's participation in the pilot programs.

"My child has permission to participate in small focus groups and sample activity sessions that may be used in public relation materials for the Boys and Girls Club of Worcester as well as in their collaboration with Worcester Polytechnic Institute.

Please mark one of the options: ______YES______NO

Initial here: X__________________

Photograph and video consent is also requested of your child. This will allow us to photograph your child in pilot sessions that may later become part of a video documenting the efforts of our project for the BGCW. **Note:** Photo/video consent is not required for focus group participation.

"My child's photograph/video has permission to be used in public relation materials for the Boys and Girls Club of Worcester as well as in their collaboration with Worcester Polytechnic Institute (includes, but is not limited to having his/her photo or name is newspapers, newsletters, Club website, partner website, YouTube, Club's Facebook and Twitter page)".

Please mark one of the options: ______YES______NO

Initial here: X__________________

Student's Name: (please print) ____
Student's Grade: ____
Print name of Parent/Guardian: (print) ____________________________________
Signature of Parent/Guardian: (sign) ____________________________________
Relation to Student: ____
Date: __________________

WPI

BOYS & GIRLS CLUB
of Worcester

Permission slip for pilot sessions:

Permission Slip

The Boys & Girls Club of Worcester have scheduled an activity/event that requires a permission form that must be completed in full by a parent or guardian. Failure to submit this form by the designated date will result in not being able to participate in the activity/event.

Please complete the form below and return by November 30, 2015

**** (Keep the activity/event information for your own reference) ****

What	**WPI STEM Activity**
Where	**Boys & Girls Club of Worcester- Learning Center**
When	**December 2nd & 3rd (Girls)**
Age Group	**10-13 years old**
Transportation	**N/A**
Start	**6 p.m. (sharp)**
End	**7:30 p.m. (sharp)**
Cost	**FREE**
Contact	**Tomas Aponte (508) 753-3377**
Information	**This activity will be with our WPI student volunteers. One permission slip per member please!**

**** CLUB T-SHIRT MUST BE WORN ON ALL TRIPS!!! ****

Tear off and return this portion, keep top portion for your reference.

Activity: WPI STEM Activity (December 2nd & 3rd)

Child's Name: ____ **Age:** ________

Address: ____

Parent/Guardian Name: _______________________________ **Tel #:** __________

Alternate Contact Name: _______________________________ **Tel#:** __________

By signing this form I certify that I request and give my permission for my child to participate in this activity/event on the above date. I also hereby release the Boys & Girls Club of Worcester, their staff and chaperones, plus any of their lawful representatives from all liability and I waive any claims against them.

In case of accident, I also give permission to a staff member of the Boys & Girls Club of Worcester to act on my behalf in the event of an emergency situation.

Parent/Guardian Signature:____

Appendix G: Pre- & post-test of pilot sessions

Pre- and post-test for kids involved in the pilot sessions:

Pre-Worksheet:

1. I do not like the way science and math is taught to me
   (1=not at all, 5= very much so)

2. I feel confident in my science and math abilities
   (1=not at all, 5= very much so)

3. What does STEM stand for?
   S________________ T_______________ E_______________ M_______________

4. Check all of the activities you are interest in:
   - ❑ Engineering
   - ❑ Aeronautics (space)
   - ❑ Aquatic/Marine science
   - ❑ Chemistry
   - ❑ Computer science
   - ❑ Physics
   - ❑ Mathematics
   - ❑ Life science (Biology)
   - ❑ Making computer games
   - ❑ Robotics

Post-worksheet:

1. I do not like the way science and math is taught to me
   (1=not at all, 5=very much so)

2. I feel confident in my science and math abilities
   (1=not at all, 5= very much so)

3. What does STEM stand for?
   S________________ T_______________ E_______________ M_______________

4. How have these activities changed your opinion of math and science?
   ____
   ____

Post-test for parents/guardians of kids involved in the pilot sessions:

GREAT FUTURES START HERE.

BOYS & GIRLS CLUB
OF WORCESTER

WORCESTER POLYTECHNIC INSTITUTE · 1865 · WPI

We would like to thank you for your permission in allowing your child to participate in our pilot sessions for a STEM (Science, Technology, Engineering, and Math) program that will be set to begin in Spring of 2016. Your child actively participated in engineering activities such as the construction of a marshmallow-spaghetti tower and building a hovercraft racer, as well as creating their own ice-cream sundaes with chemistry applications. We would appreciate any feedback you or your child has had after participating in this program. Thank you!

1. Did your child express interest in the STEM (Science, technology, engineering, and mathematics) after the pilot sessions held with WPI students?

2. Did your child explain topics covered in the program? Did they want to re-create any projects at home?

3. Did your child express any excitement and enthusiasm towards the program coming next spring? (Would they want to participate?)

4. Do you have a background in science, technology, engineering, and math?

5. Do you have any interest towards STEM related fields?

6. Do you have any further questions?

Child's Name:____

Parent/Guardian Signature: ________________________ Date:____________

Examples of pre- and post-tests:

Pre-Worksheet:

1. I do not like the way science and math is taught to me
   (1=not at all, 5= very much so)

2. I feel confident in my science and math abilities
   (1=not at all, 5= very much so)

3. What does STEM stand for?
   S__________ T__________ E__________ M__________

4. Check all of the activities you are interest in:
   - [x] Engineering
   - [ ] Aeronautics (space)
   - [x] Aquatic/Marine science
   - [x] Chemistry
   - [ ] Computer science
   - [ ] Physics
   - [x] Mathematics
   - [ ] Life science (Biology)
   - [x] Making computer games
   - [x] Robotics

Name:

Post-worksheet:

1. I do not like the way science and math is taught to me
   (1=not at all, 5=very much so) 1 2 3 4 5

2. I feel confident in my science and math abilities
   (1=not at all, 5= very much so) 1 2 3 4 5

3. What does STEM stand for?
   S cience T eckholesy E ngerneving M athmatics

4. How have these activities changed your opinion of math and science?
   They changed it by teaching me new stuff and doing other things.

Example of pre- and post-test:

Name:

Pre-Worksheet:

1. I do not like the way science and math is taught to me
   (1=not at all, 5= very much so) 1 2 3 4 5
2. I feel confident in my science and math abilities
   (1=not at all, 5= very much so) 1 2 3 4 5
3. What does STEM stand for?
   S ciece T o E Ruption M ars
4. Check all of the activities you are interest in:
   - [x] Engineering
   - [x] Aeronautics (space)
   - [x] Aquatic/Marine science
   - [x] Chemistry
   - [x] Computer science
   - [x] Physics
   - [x] Mathematics
   - [x] Life science (Biology)
   - [x] Making computer games
   - [x] Robotics

Post-worksheet:

1. I do not like the way science and math is taught to me
   (1=not at all, 5=very much so) 5
2. I feel confident in my science and math abilities
   (1=not at all, 5= very much so) 1

   * Member said "Technology I want to write "tech abilitie

3. What does STEM stand for?
   S cience T ecability E ngerning M ath
4. How have these activities changed your opinion of math and science?
   Science changed my life.

Appendix H: Full curriculum for the program

The following pages include the full version of the curriculum developed for the Boys & Girls Club of Worcester. The lessons are organized as shown in the table below.

Unit Title	Lesson Title
Unit 1: Intro to STEM	Skewer Through a Balloon
	Seven Layers Density Column
	Pop Rocks Experiment (Optional)
Unit 2: Activities in Motion	Hovercraft Racers
	Balloon Launcher
Unit 3: Activities in Engineering	Marshmallow Design Challenge
	Bridge Building
Unit 4: Activities in Sound	Introduction to Sounds and Pitches
	Build a Band
Unit 5: Gravity and Forces	Egg Drop
Unit 6: Circuits	Flashlight Dissection
	Chibitronics
Unit 7: Party Science	Skewer Through a Balloon
	Make Your Own Ice Cream
Back-up Units	Spacecraft on Mars
	Make Your Own Watercraft

Table of Contents

Introduction

"How to Use" STEM Curriculum:

We created a curriculum that consists of seven core units. Each unit contains activities that are relevant to that week's topic and that coincide with Massachusetts Common Core and the Next Generation Science Standard, which were taken from the organization sites. Also, within each unit is a manual guide, including a detailed curriculum lesson plan and any necessary teacher/student quick sheets for the respective lessons. We designed teacher quick sheets for each activity that contain necessary and succinct information about the activity that the instructor can quickly review. Dependent on the lesson, we included a student reference sheet if it is necessary for them to receive additional information to help them perform the activity, beyond the teacher's instructions. The curriculum topics are placed in an order such that discussions can be built from week to week. However, we built the curriculum to be flexible to meet the needs of the classroom and the instructor, allowing the instructor to execute the curriculum in an order that best complements the classroom. Additionally, to permit flexibility, we provided back-up lessons and incorporated activity extensions in each lesson to be completed at the end of the session (if time permitted), or as a follow-up activity for the upcoming session.

Unit 1: Materials List

Lesson 1: Skewer Through a Balloon

Materials:
- Latex balloons
- Bamboo cooking skewer
- Cooking oil
- Sharpie pen/marker

Lesson 2: Several Layers Density Column

Materials:
- Light Karo Syrup
- Water
- Vegetable Oil
- Dawn dish soap (blue)
- Rubbing alcohol
- Lamp oil
- Honey
- Graduated cylinder (per group/student)
- Food coloring or True Color Coloring Tablets
- Food baster
- 9 oz. portion cups

Lesson 3 (optional): Pop Rocks Experiment

Materials:
- Pop Rocks
- Soda in 2 liter bottles (get a variety--diet works best)
- Balloons
- Funnels
- Chip clips
- Small cups

STEM Introduction Unit: "How does that happen?"

The purpose of these activities is to introduce the wonder behind STEM (Science, Technology, Engineering, and Mathematics) disciplines. By igniting the interest and fascination behind STEM by including all encompassing lesson plans and discussion, the students will begin to understand how vastness of the STEM jobs.

Lesson 1: Skewer Through a Balloon

(*Physical Science)*

Time: 20-25 minutes
Group Size: Individual

Introduction:

In this lesson we are going to do our best to get this skewer through our balloons! By taking your wooden skewers, I want all of us to blow up our balloons and attempt to get the skewer completely through the balloon. This may seem a little crazy, but we will have to test out the experiment ourselves! Before we begin we need to make our first scientific hypothesis so, do you think the balloon will pop? Or is it possible to push the skewer through and through?

Materials:

- Latex balloons (2 per student)
- Wooden cooking skewer (2 per student)
- Cooking oil (1 container per class)
- Sharpie pen/marker (1 per student)

Procedure:

1. The first step is to inflate the balloon until it's almost nearly full size and then let out about ⅓ of the air. Tie a knot at the end of the balloon. The balloon should be smaller than the length of the skewers.
2. Examine the balloon and try to find an area where you can push the skewer through
3. You can try to dip the wooden skewer into the cooking oil, which can act as a sealant.
4. Be careful not to prick yourself or the balloon with the skewer!

For the Teacher:

1. If students are unable to do the task it is likely because they are putting the skewer in the wrong way. Give students a new balloon and a marker. Have the following discussion before showing the correct way. This will assess understanding of the stress placed on the balloon.
2. Tell students to blow up the new balloon, and use the Sharpie pen/marker to draw about 10-15 dots on the balloon. The dots should be about the size of a head of a match. Be sure to draw them at both ends and in the middle of the balloon.
3. Inflate the balloon halfway and tie at the end. Observe the various sizes of the dots all over the balloon.
    a. Where are the dots on the latex molecules stretched out the most?
    b. Where are they stretched out the least?

    c. Dip the wooden skewer in the vegetable oil and use your fingers to coat the skewer with oil.
4. Dip the wooden skewer in the vegetable oil and use your fingers to coat the skewer with oil.
5. Use the observations that you made previously about the dots on the balloon to decide the best spot to put the balloon with the skewer.
6. Have the students place the sharpened tip of the skewer on the thick end of the balloon and push the skewer into the balloon. Just use gentle pressure (and maybe a little twisting motion) to puncture the balloon.
7. Push the skewer all the way through the balloon until the tip of the skewer touches the opposite end of the balloon (other thick portion). Keep pushing until the skewer penetrates the rubber.
8. Gently remove the skewer from the balloon when you are done!

For the Student (*Can be printed or discussed):

1. Take your first balloon and blow it up as much as you can (without popping it), and release a little bit of air so that you can tie it
2. Tie the balloon at its ends
3. Take your skewer and choose a spot on the balloon to push it all the way through!
4. It’s ok if you pop your first try! You will have more chances.
5. Take your second balloon from your teacher, and a marker
6. Put small marker dots all over the balloon (like the size of a tic tac)
7. Follow the teacher’s instructions!

Conclusion:

There is a little secret behind being able to put the skewer through the balloon. The secret is in finding the part of the balloon where the molecules are under the least amount of stress or strain. After you all drew on the balloon with the marker, you should have been able to see where the dots were smaller and larger. The small parts were your areas of less stress, and those were found on the ends of the balloon. When the point of the skewer is positioned at the ends of the balloon, the solid object passes through the inflated balloon without popping it.

If you could see the rubber that makes up a balloon under a microscope, you would see many long strands or chains of molecules. These long strands of molecules are called *polymers*, and the polymer chains are so elastic that it allows the rubber to stretch. Even before drawing the dots on the balloon, you probably noticed that the middle of the balloon stretches more than either end. Therefore, to get it through you have to pierce the balloon at a point where the molecules are the least stretched out! However, the molecules around the holes you made that stretched around the skewer, were so tight that they were able to keep the air inside the balloon instead of rushing out.

For engineers, this a way for them to understand the stress and tension placed on certain objects. Before the begin construction, designing, or building, engineers must understand the stress of their materials to make sure they can withstand the pressure!

Objectives/Outcomes:

- Students are able to begin developing hypotheses based on previous knowledge, and test their hypotheses

- Students are able to explain to their peers the phenomena and the discussion behind it
- The discussions of polymers and tension coincide with the common core expectancies of science courses in grades 6 through 8.
- Students are encouraged to test this out at home and have their parent's perform a taste test as well.

Common Core:

- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events. (Grades 6-8)

Next Generation Science Standards:

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2)(MS-PS2-4)

Inspired by: Steve Spangler Science Experiments (http://www.stevespanglerscience.com/lab/experiments/skewer-through-balloon/)

Lesson 2: Seven Layer Density Column

(Chemistry and Physical Science)

Time: 30 Minutes
Group Size: Individual (if materials permit- if not in groups of 2 students)

Introduction:

Environmental engineers rely on their understandings of chemical and physical properties of materials. For example, they might measure the pH level (level of acid), which is one important chemical property, especially for environmental engineers who focus on water quality. *Did you know that engineers work specifically with the water that we drink? How do they help us keep our water clean?* Then, these engineers will have to find a way to calculate the densities. To calculate density, we must measure the mass of an object and its volume. Then we divide the mass by the volume. This gives us the density of that object. We are going to use small cylinders to test out density.

I want each of you to think that you are an environmental engineering and you must test the quality of water in Indian Lake in Worcester! We have all of the contents that you can find in the lake (gross!), but we need to figure out which contents are more dense than the others!

Opening Questions:

1. *What is Density? Mass? Volume?*
2. What are some important physical properties that environmental engineers might also be concerned about? (Listen to student ideas. Possible answers: Weight, mass, area, volume, density.) We are going to focus on mass and density in today's activity.
3. How do you think we can test density of liquids? (So you can't just put it on a normal scale)
    a. *Mass/volume*

Materials:

- Light Karo Syrup
- Water
- Vegetable Oil
- Dawn dish soap (blue)
- Rubbing alcohol
- Lamp oil
- Honey
- Graduated cylinder
- Food coloring or True Color Coloring Tablets
- Food baster
- 9 oz. portion cups

For the Teacher:

- Review the procedure before the class session
- (Optional) Write out values on a whiteboard or poster so that children are able to see the density chart

- Remind the students of the exact amount (8 ounces)

Procedure:

1. Measure 8 ounces of each fluid with the food baster into individual 9 ounce cups and label each cup.
2. Color each of the liquid differently (some may already have color)
    a. May not be able to color the vegetable oil or honey
3. Start your column (in the graduate cylinder) by pouring in the honey
4. Now you will pour each liquid in slowly into the container, ONE AT A TIME
    a. IN THIS ORDER:
        i. Honey
        ii. Karo syrup
        iii. Dish soap
        iv. Water
        v. Vegetable oil
        vi. Rubbing alcohol
        vii. Lamp oil
5. Try to make sure the liquids do not touch the sides of the cylinder when you are pouring them in. (It's ok if the fluids mix a little bit, they will even themselves out)

Conclusion:

The Science Behind it: Even if you have the same amount (volume) of two liquids, they will likely have different weights because they have different masses. The liquids that weigh more (have a higher density) will sink below other liquids that have a lower density.

Density is basically how much "stuff" is smashed into a particular area, but you can also look at it as an object's mass and volume. Remember the all-important equation: Density = Mass divided by Volume. *Did any of you know this equation before? Why might we use this equation?* Based on this equation, if the weight (or mass) of something increases but the volume stays the same, the density has to go up. Likewise, if the mass decreases but the volume stays the same, the density has to go down. Lighter liquids (like water or rubbing alcohol) are less dense than heavy liquids (like honey or Karo syrup) and so float on top of the more dense layers.

1. *What does density mean?*
2. *Had you learned about density as Mass divided by Volume in school?*
3. *What kind of STEM professionals would have to test density?*
4. *What are objects we would test the density for?*
5. *Why do you think it is that the colors do not mix?*

Objectives/Outcome:

- Student should be able to explain the difference and relationship between mass and density.
- Students are able to take accurate measurements of mass and volume, and apply the respective values to comparison
- Relate hydrophobicity and miscibility to density (Can discuss the solubility of the solutions, and why they do not ultimately mix)

Common Core:

- Describing the nature of the attribute under investigation, including how it was measured and its units of measurement. (Grades 6 - 8)
- Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered. (Grades 6 - 8)
- Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered. (Grades 6 - 8)
- Knowledge gained from other fields of study has a direct effect on the development of technological products and systems. (Grades 6 - 8)

Next Generation Science Standards:

- Properties of Matter: Differentiate between volume and mass. Students can define density. (5-PS1-3.2.9)
- Make observations and measurements to identify materials based on their properties (5-PS1-3.)

Activity Extension:

Show or write out the following table of density values and allow the advanced students identify the densities of their materials used. Ask questions about the densities involved:

- What makes a substance 'more dense'?
- Compare substances: what is more dense, honey or vegetable oil?
- Why do the substances not mix?
    - *The substances are not soluble with each other (they don't mix)*

Material	Density
Rubbing Alcohol	.79
Lamp Oil	.80
Baby Oil	.83
Vegetable Oil	.92
Ice Cube	.92
Water	1.00
Milk	1.03
Dawn Dish Soap	1.06
Light Corn Syrup	1.33
Maple Syrup	1.37
Honey	1.42

You can set up a scale and measure each of the liquids you poured into your column. Make sure that you measure the weights of equal portions of the liquid. Make your own chart!

- This will allow students to understand that density and weight are closely related, but are independent of volume.
- The densities of the liquids above are all based on manufacturer results...your chart should look different since each company uses different densities in their products (measured in g/cm3 or g/mL)
- Density= (how much stuff is in one area) compares something's mass and volume (Density=Mass/Volume)

This means that if the weight or mass of something increases (but the volume stays the same) the density will increase-- if mass decreases but volume stays the same, density will decrease

Inspired by: Steve Spangler Science Experiments (http://www.stevespanglerscience.com/lab/experiments/seven-layer-density-column/)

(Optional: Expensive Unit) Lesson 3: Pop Rocks Experiment

(Chemistry)

Time: 20 minutes
Group Size: Groups of 2

Introduction:

How many of you guys have had pop rocks before?! Well if you have, can you tell me what they do? THEY POP INSIDE YOUR MOUTH. In today's lesson we are going to try to understand the science behind these carbonated candies, and do an experiment involving carbon dioxide!

1. Can anyone tell me what carbonated means?
2. What is carbon dioxide? Where else might we see it?
3. Did you know there was this much science behind candy?!

Materials:

- Pop Rocks
- Soda in 2 liter bottles (get a variety--diet works best)
- Balloons
- Funnels
- Chip clips
- Small cups

Procedure:

1. Use the funnel to pour a packet of pop rocks into each balloon

2. Use the chip clip to keep the pop rocks contained in the bottom of the balloon
3. Before you put the balloon on top of the soda, ask yourself the following questions:
   a. What is going to happen to the soda?
   b. What is going to happen to the balloon?
4. Take the cap off of the soda, and carefully put the balloon around the mouth of the bottle.
5. When you are ready, release the chip clip!
   a. Shake the bottle to make the reaction happen quicker!
6. Take note of what is happening!

Conclusion:

The Science behind it: In each little pop rock there is a packed in amount of pressurized carbon dioxide gas. The gas is the bubbles which make the popping sound, when they burst free from their candy shells! Take a large pop rock and use a spoon to break it against a table, you should be able to hear the rock ‘POP’, like on your tongue.

So what causes the balloon to inflate? The CO2 (carbon dioxide) in the candy is not enough gas to cause the balloon to inflate so what is doing it? The soda you are mixing it with also contains pressurized carbon dioxide gas (that’s why it is called carbonated soda). When the candy and the soda mix, the carbon dioxide wants to escape from mixing with the high fructose corn syrup in the soda and can only travel up--to the balloon!

Common Core:

- Knowledge gained from other fields of study has a direct effect on the development of technological products and systems. (Grades 6 - 8)

Next Generation Science Standards:

- A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2)
- Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. (MS-PS3-2)

Inspired by: Steve Spangler Science Experiments

Seven Layer Density Column Teacher Quick Sheet

Opening Discussion:

Environmental engineers rely on their understandings of chemical and physical properties of materials. For example, they might measure the pH level (level of acid), which is one important chemical property, especially for environmental engineers who focus on water quality. *Did you know that engineers work specifically with the water that we drink? How do they help us keep our water clean?* Then, these engineers will have to find a way to calculate the densities. To calculate density, we must measure the mass of an object and its volume. Then we divide the mass by the volume. This gives us the density of that object. We are going to use small cylinders to test out density.

I want each of you to think that you are an environmental engineering and you must test the quality of water in Indian Lake in Worcester! We have all of the contents that you can find in the lake (gross!), but we need to figure out which contents are more dense than the others!

1. *What is Density? Mass? Volume?*
2. What are some important physical properties that environmental engineers might also be concerned about? (Listen to student ideas. Possible answers: Weight, mass, area, volume, density.) We are going to focus on mass and density in today's activity.
3. How do you think we can test density of liquids? (So you can't just put it on a normal scale)
    a. *Mass/volume*

Procedure (To be explain to students):

1. Measure 8 ounces of each fluid with the food baster into individual 9 ounce cups and label each cup.
2. Color each of the liquid differently (some may already have color)
    a. May not be able to color the vegetable oil or honey
3. Start your column (in the graduate cylinder) by pouring in the honey
4. Now you will pour each liquid in slowly into the container, ONE AT A TIME
    a. IN THIS ORDER *(*Write the order of the fluids on the board):*
        i. Honey
        ii. Karo syrup
        iii. Dish soap
        iv. Water
        v. Vegetable oil
        vi. Rubbing alcohol
        vii. Lamp oil
5. Try to make sure the liquids do not touch the sides of the cylinder when you are pouring them in
    a. It's ok if the fluids mix a little bit, they will even themselves out

Materials:

- Light Karo Syrup
- Water
- Vegetable Oil
- Dawn dish soap (blue)
- Rubbing alcohol
- Lamp oil
- Honey
- Graduated cylinder
- Food coloring or True Color Coloring Tablets
- Food baster (to dispense fluids)

- 9 oz. portion cups

Closing Discussion/Questions:

1. What does density mean?
2. Had you learned about density as Mass divided by Volume in school?
3. What kind of STEM professionals would have to test density?
4. What are objects we would test the density for?
5. Why do you think it is that the colors do not mix?

The Science Behind it: Even if you have the same amount (volume) of two liquids, they will likely have different weights because they have different masses. The liquids that weigh more (have a higher density) will sink below other liquids that have a lower density.

Density = Mass divided by Volume. *Did any of you know this equation before? Why might we use this equation?* Based on this equation, if the weight (or mass) of something increases but the volume stays the same, the density has to go up. If the mass decreases but the volume stays the same, the density has to go down. Lighter liquids (like water or rubbing alcohol) are less dense than heavy liquids (like honey or Karo syrup) and so float on top of the more dense layers.

(Optional) Pop Rocks Experiment Teacher Quick Sheet

Introduction Discussion:
How many of you guys have had pop rocks before?! Well if you have, can you tell me what they do? THEY POP INSIDE YOUR MOUTH. In today's lesson we are going to try to understand the science behind these carbonated candies, and do an experiment involving carbon dioxide!

1. Can anyone tell me what carbonated means?
2. What is carbon dioxide? Where else might we see it?
3. Did you know there was this much science behind candy?!

Materials:

- Pop Rocks
- Soda in 2 liter bottles (get a variety--diet works best)
- Balloons
- Funnels
- Chip clips
- Small cups

Procedure:

1. Use the funnel to pour a packet of pop rocks into each balloon

2. Use the chip clip to keep the pop rocks contained in the bottom of the balloon
3. Take the cap off of the soda, and carefully put the balloon around the mouth of the bottle.
4. When you are ready, release the chip clip! (Shake the bottle to make the reaction happen quicker!

Concluding Discussion/Questions:

1. Why did the balloon inflate?
2. What would happen if we used less pop rocks?
3. What if we used a smaller container of soda?

*Begin a class discussion and allow students to compare ideas on CO_2 and the carbonation within soda
The Science behind it: In each little pop rock there is a packed in amount of pressurized carbon dioxide gas. The gas is the bubbles which make the popping sound, when they burst free from their candy shells! Take a large pop rock and use a spoon to break it against a table, you should be able to hear the rock 'POP', like on your tongue. So what causes the balloon to inflate? The CO2 (carbon dioxide) in the candy is not enough gas to cause the balloon to inflate so what is doing it? The soda you are mixing it with also contains pressurized carbon dioxide gas (that's why it is called carbonated soda). When the candy and the soda mix, the carbon dioxide wants to escape from mixing with the high fructose corn syrup in the soda and can only travel up--to the balloon!

Unit 2: Materials List

Lesson 1: Hovercraft Racers

Materials:

- 1 CD (per student/group)
- 1 regular soda/water bottle cap (per student/group)
- 1 soda/water bottle cap with closeable nipple (per student/group)
- 1 large balloon (per student/group)
- Drill (to put holes in the caps)
- Hot-glue gun
- Meter stick(s)
- Stopwatch

Lesson 2: Balloon Launcher

Materials:

- Plastic straws
- Plastic bags (grocery bags)
- Paper Streamers
- 25 ft. of thick fishing line (per group/student)
- Long, tube-shaped balloons
- Tape measure or meter stick

Lesson 1: Hovercraft Racer

(Physical sciences and engineering)

Students will learn through a hands-on activity how friction impacts motion. They will do so through the creation of hovercrafts that use air to levitate a CD. Students will learn from this how the air underneath an object reduces friction while it is in motion.

Time: 45 Minutes
Group Size: Individual

Introduction:

"*Friction"* is a force that happens when things rub against each other. Friction is also something that can slow things down. Different objects have different amount of friction when they rub together; however, when surfaces do not rub against each other, there is no friction between them. So, to reduce friction, objects can't touch! For example, boat engineers and builders know that friction between a boat and water is something that slows the boat down. Over the years, they have been figuring out ways to design boats so that they do not touch water very much, but still float. In 1877, an engineer named Sir. John Thornycroft came up with a method to design boats to ride on a cushion of air. Basically, he used a large fan and motor to force air underneath of the craft! Eventually, the air pressure was large enough to lift the vehicle off the surface.

Engineers starting designing "flying boats" and other airplanes that can lift off of a water surface. In 1955, another engineer named Christopher Cockerell tested out a new vehicle called the hovercraft. This would be a vehicle that can travel on practically any surface. Even Ford Motor Company tried to make a "hovercar" called the Glideair in 1959. Now, hovercrafts are used for rescue work on rapidly moving rivers and thin ice, cargo transport and ferrying work), and by the military to transport troops and equipment from boats to the shore.

In this activity, we need your help! We have been stranded on a small island on Lake Quinsigamond. We must find a way to get our note across the large body of water. We are going to build our own model hovercraft to learn why suspending something on a cushion of air might help it slide over certain surfaces. Then, we will be able to test our idea to see how far we would make it!

Opening Discussion Questions:

1. How do objects move together without having friction?
   a. *If they are not touching*
2. Why does the hovercraft move differently on different surfaces? (test on all surfaces)
   a. *On the carpet there isn't enough resistance to hold up the CDs, it moves better with smoother surfaces*
3. Why did we put different amounts of holes? How many holes did yours have?
   a. *With more holes, air escapes faster so the CD glides better*
   b. *With one hole the air escapes slower making the racer last longer…to win races!*

Materials: (highly recommended to buy additional material)

- 1 CD for each student/group
- 1 regular soda/water bottle cap for each student/group

- 1 soda/water bottle cap with closeable nipple for each student/group
- 1 large balloon for each student/group
- Drill (to put holes in the caps)
- Hot-glue gun
- Meter stick(s)
- Stopwatch

For the Teacher (Before Prep):

1. Gather supplies, but ask students to bring in their own CDs
2. Prepare the materials—use a saw to cut the tops of the bottles at the neck. Save the top and cap. Drill 1-3 holes in each bottle cap with a different number in each cap. This is so that students can compare with other students who had different holes. (Suggestion: Take the bottle caps off before sawing off the caps)
3. **With students:** discuss friction. Ask them about forms of transportation they know about that deal with friction.

Procedure:

1. Have the students grab one bottle cap with 1-3 holes drilled. Be sure some students have one with one hole, some have a bottle cap with two holes, and some have a bottle cap with three holes.
2. Have the students carefully use the hot glue gun to attach the caps to each side of the CDs, with the holes in the caps centered over the holes in the middle of the CDs as shown below. Be sure to completely seal the space between the cap and CD.
3. Let the glue cool for a few minutes. Have students blow up their balloons, then pinch the neck so that air doesn't escape while attaching the balloon to the bottle cap so it looks like the picture below. Make sure the nipple is closed before releasing the balloon.
4. Place the hovercraft racer on a smooth, flat surface (i.e. floor) and open the nipple. Tap the sides of the racer, and see how it glides over the surface.
5. Have the students tap their hovercrafts down the length of a meter stick and use a stopwatch make note of the time it takes to travel a certain distance.
6. Calculate the velocity to see which student's hovercraft went the fastest.

Conclusion Discussion Topics:

1. Have the students brainstorm and discuss in their groups—encourage all ideas to be heard and creative.
2. Ask them if they can think of ways (no matter how crazy) to improve their design? If not, what are ways to keep the air flowing since a balloon ends so quickly.
3. What changes would you make if you needed to have a hovercraft carry heavy cargo?
    a. *(If they don't answer) How much would the balloons hold? How would you carry cargo?*

Outcome/Objectives:

1. Students gain an understanding of friction and how it slows objects down and acts as a way of controlling motion.
2. Understand how and why a hovercraft floats

3. Students are able to predict and hypothesize surfaces that may influence friction based on problem solving techniques.
4. Students recognize that friction is understood by engineers and is used to understand how to control the motion of certain objects.

Common Core Standards:

- Brainstorming as a group problem solving design is a way for each student to express their ideas (Grades 6-8)
- Transportation vehicles are made of subsystems such as structural propulsion, suspension, guidance, control, and support, that must function together as a system to work effectively (Grades 6-8)
- Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields (Grades 9-12)
- Designs are continually checked and critiqued, and the ideas of the design are refined and improved (Grades 9-12)

Next Generation Science Standards:

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)
- Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success (MS-ETS1-3)
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

Activity Extension:

For students that have moved forward with their construction, encourage them to begin racing each other. Lay out pieces of tape so that children may race from one end of the room to the other. By comparing the number of holes, students may want to transform their hovercraft to become the optimal racer. Encourage students to use materials around the room to boost their hovercraft design!

Inspired by: eGFI Teacher Resources (http://teachers.egfi-k12.org/hovercraft-racers/)

Lesson 2: Balloon Launcher

(Aerodynamics and Newton's Three Laws of Motion)

Time duration of lesson: 1 hour
Group Size: 2 students per group

Introduction:

So just like the hovercraft activity, we are going to move on to another activity that involves motion. We are going to test just how much pressure we can get from the air being pushed out of the balloon.

Engineers of all disciplines use their understanding of Newton's laws of motion to quantify the "invisible" forces acting on all objects. *Have any of you heard of Newton's Laws? Who can tell me what gravity is?* Many of you have hear about satellites, and many even how sometimes they are pulled out of orbit when the forces become too weak. To keep them something in orbit, engineers look at Newton's second law! They have created inventions such as thrusters that burn fuel and boost the rocket forward! So, this means they create extra boosters to push the shuttle farther when it is falling out of orbit!

(*For the Teacher): Give a demonstration: if you can, get a skateboard or something on wheels you can stand on. Grab a basketball and try to throw it to someone else. Have the students see what happens? This will show the students that when you roll backwards you are really being propelled from forces in the opposite direction. This activity demonstrates all three of Newton's laws of motion. The air pushing out of the balloon cause an equal reaction and force, causing movement. The more air initially in the balloon, the further the balloon travels along the string because the action force is greater. Similarly, if there is only a small amount of air initially in the balloon, the balloon travels a shorter distance.

We are going to test out the most creative ways we could pass information (attached to our balloons) from one point to another! Your friend is in the room next to you and you need to get them some information—write the message on your balloon when you are ready, and let it fly!

Law #1: Objects at rest will stay at rest, and objects in motion will stay in motion in a straight line unless they are acted upon by an unbalanced force. (law of inertia)

Law #2: Force is equal to mass multiplied by acceleration. (F = ma)

***Law #3: For every action, there is always an opposite and equal reaction.**

Opening Discussion Points/ Questions (if necessary):

- Have any of you heard about Newton's Laws?
- What are some of the objects/transportation devices NASA has sent into space?
- Why would we have to worry about gravity?
- What is the purpose of the thrusters?

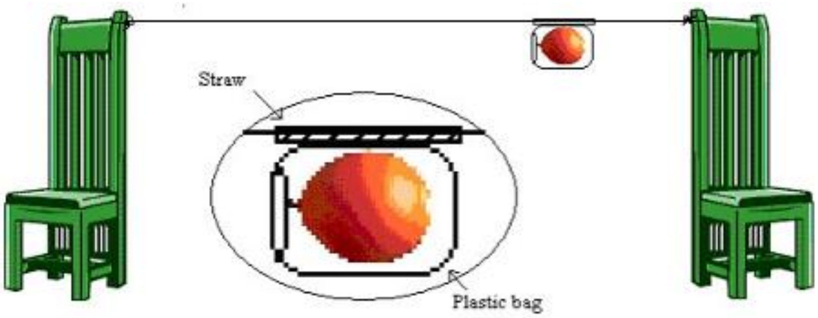
Materials:

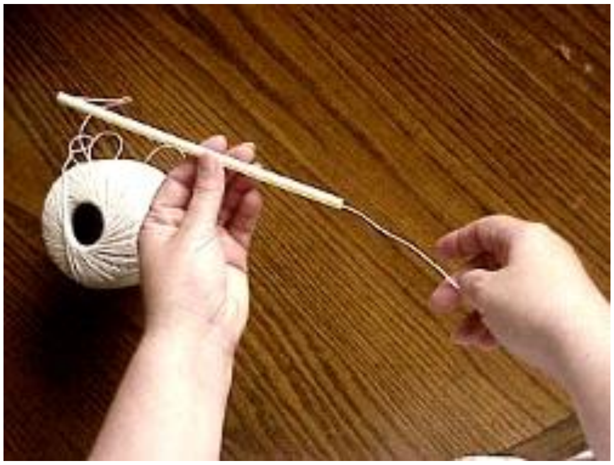
- Plastic straws
- Plastic bags (grocery bags)

- Paper Streamers
- 25 ft. of thick fishing line
- Long, tube-shaped balloons
- Tape measure or meter stick

For the Teacher Procedure:

- This will be the set-up of the activity so make sure there are enough chairs or locations where the string may be tied
- Have students vote on which of Newton's three laws of motion applies to the flight of rockets. Tabulate votes on the board. (Answer: Trick question! All three laws apply.)
- Once completed: Have students measure the distance their balloon rocket traveled on the string and complete the worksheet if necessary.
- Allow students to discuss with each other and race their balloons as an extension





Procedure (For the Student):

1. Tape a drinking straw along the side of a plastic bag (see diagram) *can also just tape balloon to straw*
2. Tape streamers along the open edge of the plastic bag.
3. Thread the string through the straw.
4. Tie each end of the string to a chair, and pull the chairs apart so that the string is tight (see diagram).
5. Position the bag at one end of the string, with the open end of the bag facing toward the chair.
6. Blow up a balloon and put it into the bag, holding the balloon closed.

7. Countdown to zero, and let go of the balloon!
8. Continue testing this with balloons blown up the different sizes (small-large)

Conclusion/ Closing Discussion Points:

- What did we learn about forces and gravity?
- Who can tell me one of Newton's Laws that we experimented today?
- Wrap up the lesson with insight on the applied STEM topics and pull out any topics or interest the students encountered.

Rockets and rocket-propelled flight has been in use for more than 2,000 years. People in ancient China used gunpowder to make fireworks and rockets; anything that would act as a booster! Now, aerospace engineers have gained enough knowledge to make rockets fly farther, faster, higher and more accurately. To understand how rockets work with gravity we look at Sir Isaac Newton's three laws of motion. It is important for engineers to understand Newton's laws because they not only describe how rockets work, they explain how everything that moves or stays still works!

Activity Extension:

- Tape pennies to the outside of the rocket to increase the mass. How does increased mass affect the flight of the rocket? (Answer: Because of Newton's second law, the same force exerted upon a larger mass will result in a lower acceleration – the rocket will not go as far!)
- See possible worksheet below

Objectives/Outcomes:

- Understand practical applications of Newton's Laws of Motion
- Students can use the model of the balloon to understand the different forces that may be applied to space travel
- Students can collect data from their experimental trials

Common Core:

- Science as Inquiry: Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. (Grades 6-8)
- Science and Technology Standard: Collect data about the performance of a proposed object, tool, process, or system under a range of conditions. (Grades 6-8)

Next Generation Science Standards:

- Motions and Forces (4-8) For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)

- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MSPS2-2)

Inspired by: eGFI Teacher Resources (http://teachers.egfi-k12.org/balloonautics/)

Activity Extension Worksheet:

Team Name: ____ *Date:* ____________________

Worksheet Action-Reaction!

1. What is Newton’s first law of motion and give an example from the experiment?

2. What is Newton’s second law of motion and give an example from the experiment?

3. What is Newton’s third law of motion and give an example from the experiment?

4. Draw a picture of your “Rocket.” Label the where there are forces!

Hovercraft Teacher Quick Sheet

Objective: Objective: Students will be building small hovercrafts, and gain understanding on the impact of friction as well as recognition of problem-solving techniques used in the engineering disciplines.

Materials:

- 1 CD for each student
- 1 water/soda bottle cap with a nipple for each student
- 1 water/soda bottle cap without a nipple for each student
- 1 large balloon for each student
- Hot glue gun
- Meter stick(s)

Preparation:

Before the activity, drill one, two, or three holes into each bottle cap. Be sure some bottle caps have one hole, some have two, and some have three. When passing out the caps to the students, make sure there are an even number distributed. (Suggestion: Take the bottle caps off before sawing off the caps)

Opening Discussion:

1. How do objects move together without having friction?
    a. *If they are not touching*
2. Why does the hovercraft move differently on different surfaces? (test on all surfaces)
    a. *On the carpet there isn't enough resistance to hold up the CDs, it moves better with smoother surfaces*
3. Why did we put different amounts of holes? How many holes did yours have?
    a. *With more holes, air escapes faster so the CD glides better*
    b. *With one hole the air escapes slower making the racer last longer…to win races!*

Procedure:

1. Have each student grab a bottle cap, varying who gets bottle caps with 1, 2, or 3 holes.
2. Assist the students as they glue the bottle caps to THE SHINEY SIDE OF THE CD.
3. Have the students blow up their balloons and pinch the bottoms as they attach the balloons to the caps
4. Release the pinched fingers and tap around the hovercraft to observe how it moves.
5. Have the students tap their hovercrafts down the length of a meter stick and use the stopwatch to note the time it took to travel a certain distance.
6. Have each student calculate the velocity of their hovercraft to see who's went the fastest.

Closer:

Discuss ways to improve the design. Have the students discuss: what difference the holes make? Talk about how this can be applied to the real world - are hovercrafts a viable mode of transportation for the future?

Balloon Launcher Teacher Quick Sheet:

Objectives:

Students understand practical applications of Newton's Laws of Motion, and can use the model of the balloon to understand the different forces that may be applied to space travel, and collect information from their experiment.

Opening Discussion:

- Have any of you heard about Newton's Laws?
- What are some of the objects/transportation devices NASA has sent into space?
- Why would we have to worry about gravity?
- What is the purpose of the thrusters?

Materials:

- Plastic straws
- Plastic bags (grocery bags)
- Paper Streamers
- 25 ft. of thick fishing line
- Long, tube-shaped balloons
- Tape measure or meter stick

Preparation:

- This will be the set-up of the activity so make sure there are enough chairs or locations where the string may be tied
- Have students vote on which of Newton's three laws of motion applies to the flight of rockets. Tabulate votes on the board. (Answer: Trick question! All three laws apply.)
- Once completed: Have students measure the distance their balloon rocket traveled on the string and complete the worksheet if necessary. Allow students to discuss with each other and race their balloons as an extension

Procedure:

1. Tape a drinking straw along the side of a plastic bag (see diagram) *can also just tape balloon to straw*
2. Tape streamers along the open edge of the plastic bag.
3. Thread the string through the straw.
4. Tie each end of the string to a chair, and pull the chairs apart so that the string is tight (see diagram).
5. Position the bag at one end of the string, with the open end of the bag facing toward the chair
6. Blow up a balloon and put it into the bag, holding the balloon closed.
7. Countdown to zero, and let go of the balloon!
8. Continue testing this with balloons blown up the different sizes (small-large)

Closing Discussion Points:

- What did we learn about forces and gravity?
- Who can tell me one of Newton's Laws that we experimented today?
- Wrap up the lesson with insight on the applied STEM topics and pull out any topics or interest the students encountered.

Unit 3: Materials List

Lesson 1: Marshmallow Design Challenge

Materials:

- Scissors
- 20 pieces of uncooked spaghetti (regular, not angel hair, or thin)
- 3 ft. of string that can be easily cut/broken
- 1 fresh marshmallow (not stale, mini, or jumbo)
- 3 ft. of masking tape
- Paper bag (standard lunch size)

(*Note*: this is a list of materials per group)

Lesson 2: Bridge Building

Materials:

- Safety scissors (for cutting stringers)
- Masking tape (optional, for attaching stringers to deck)
- Stapler with staples (optional, for attaching stringers to deck)
- 3-5 pound weights
- Two 15-foot pieces of rope (for cables)
- One 50-foot piece of string (for stringers/hangers)
- One 6-foot by 4-inch piece of cardboard (deck)
- 6 chairs (2 for each tower and 2 for anchors)

(*Note*: this is a list of materials per group)

Lesson 1: Marshmallow Design Challenge
(Engineering)

Time: 30 minutes
Groups: 2 students per group (3 groups)

Introduction:

This is an exercise that involves simple lessons of collaboration, scientific assumptions, and creative engineering processes. Lessons will emerge especially once the students are able to compare as teams. Encourage students to talk with their teammates about techniques and design strategies.

Students will be timed during this activity to see who can build the tallest free-standing noodle structure that can support a marshmallow. This will teach students to learn as engineers through collaborating to design, test, and improve ideas as a team as well as examining the creative process of the final product. A project such as this could be related to the work of an architect or civil engineer. Both active subsets of the engineering profession that contribute to overall topic of STEM!

The city of Worcester has gotten the attention of the Boys & Girls Club and needs help from their members. Students will have 10 minutes to brainstorm and 18 minutes to construct a freestanding building. We want to petition for our building to be put in downtown Worcester, but only one design can be chosen! Let's see who can build the tallest freestanding structure with a teammate that can hold up the weight of a marshmallow.

Materials:

*All items should be placed in a paper bag so students cannot see before starting the brainstorm period

- Scissors
- 20 pieces of uncooked spaghetti (regular, not angel hair, or thin)
- 3 ft. of string that can be easily cut/broken
- 1 fresh marshmallow (not stale, mini, or jumbo)
- 3 ft. of masking tape
- Paper bags (standard lunch size)
- For the contest—measuring tape

For the Teacher:

1. Create a 'marshmallow challenge kit' that contains all of your materials in a paper lunch bag so students are unable to see materials until they begin.
2. Display the countdown clock somewhere for all students to see (e.g. Computer)
3. Go through and carefully explain the rules numerous times and reinforce them by projecting them on a screen or somewhere students can see them.

Rules:

- Build the tallest *freestanding* structure—the winning team is the one that has the tallest structure (measured by measuring stick). It will be measured from tabletop surface to the top of the marshmallow

- The ENTIRE marshmallow must be on the top—this means you cannot cut or eat any of the marshmallow or your team will be disqualified
- Use as much or as little of the kit (this does not matter; you just cannot use the paper bag)
- Teams are free to break the spaghetti or cut up the tape and string
- The challenge is ONLY 18 minutes and will be forced to stop when the time is up

Contest Rules:
*Challenge—build the tallest freestanding structure in just 18 minutes using nothing more than 20 sticks of spaghetti, one yard of tape, one yard of string, and one marshmallow. The marshmallow must be on top and cannot be deformed to hold it in place. The structure has to stand firmly on its own; it cannot be propped up, held, or suspended from the ceiling.

Outcomes/Objectives:
1. Understanding the importance of teamwork as well as failure that is present in science and engineering
2. Understanding the strength of shapes as well as understanding weaker materials can be made strong with specific techniques involving mass distribution.
3. Further understanding that compression and tension affect the stability of a structure
4. Compare models with other students to understand why some models are stronger than other but that many ways work in the end.
5. Understanding why engineers have to consider tension, compression, and other forces when designing buildings and structures.

Common Core
- Make two-dimensional and three-dimensional representations of a designed solution model (Grades 6-8)
- Structures rest on a foundation (Grades 6-8)
- Communicate the process of technological design. Students should review their work and identify the stages of problem identification, solution design, implementation, and evaluation. (Grade 6-8)
- Evaluate completed technological designs or products (Grade 6-8)
- Student understands that technological designs have constraints (Grade 6-8)

Next Generation Science Standards:
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (secondary to MS-PS3-3)

Inspired by: eGFI Teacher Resources (http://teachers.egfi-k12.org/marshmallow-design-challenge/)

Lesson 2: Suspension Bridge Building

(Engineering, Forces)

Time: 1 hour
Groups: Two groups of 3 OR three groups of 2 (groups can be different or same as marshmallow challenge; at instructor's discretion)

Introduction:

Bridges are structures which carry people and vehicles across natural or man-made obstacles. There are many types of bridges. Based on the length of the barrier to be crossed, the amount and type of traffic as well as forces of nature (wind, tide, flood) different materials and shapes of bridges are used.

In this lesson, your team has been tasked with building a bridge across Lake Quinsigamond. For this task, you will be building the strongest of all the bridge structures - a suspension bridge. Since this bridge will be regularly used, it must withstand substantial weight. Once each group has completed their bridge, the integrity of the structure will be tested by placing weights on the bridge. Whose bridge will hold more weight?

Materials:

- Safety scissors
- Masking tape
- Stapler & staples
- 3-5 pound weights (or anything that estimates that weight)
- Two 15-foot pieces of rope
- One 50-foot piece of string (per team)
- One 6-foot by 4-inch piece of cardboard (this will be the deck for each team)
- 6 chairs (per team)

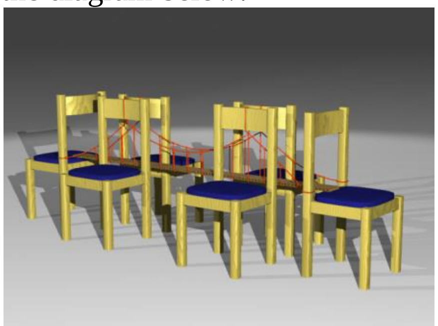
(*Note*: this is a list of materials per team)

For the teacher:

- To assist the students, practice constructing the bridge prior to the lesson

Procedure (For the Student):

- Arrange six chairs as in the diagram below:



- You and your teammates must figure out how to build the bridge. You are not allowed to anchor the deck, only the cables.

- Test your bridge by putting the weights in several different locations on the bridge. If your bridge supports the weight, congratulations!
- If you have extra time, put the weight in the middle of the bridge and start cutting the cables until the bridge collapses.

Conclusion/ Closing Discussion Points:

- What questions can we relate to the marshmallow design challenge?
- Would you make changes in your design process?

Objectives/Outcomes:

- Students build a model of a suspension bridge and test the amount of weight it will support.
- Students will learn materials can be positioned in specific patterns to form a stronger structure.

Common Core:

- Understanding that structures rest on a foundation (Grades 6-8)
- Communicate the process of technological design. Students should review their work and identify the stages of problem identification, solution design, implementation, and evaluation. (Grade 6-8)
- Evaluate completed technological designs or products (Grade 6-8)
- Student understands that technological designs have constraints (Grade 6-8)

Next Generation Science Standards:

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3), (MS-PS2- 5)
- Apply scientific ideas or principles to design an object, tool, process or system. (MS-PS2-1)
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)

Activity Extension:

For students that complete the task early, have them use their craft sticks to construct more. Never let their ideas fade; encourage students who have completed their structures to change the design. This will allow them to continue constructing but consult other techniques.

Inspired by: eGFI Teacher Resources *(*http://teachers.egfi-k12.org/lesson-bridge-swe/)

Marshmallow Design Teacher Quick Sheet:

Introduction:

This is an exercise that involves simple lessons of collaboration, scientific assumptions, and creative engineering processes. Lessons will emerge once you have the students discuss their buildings. *Why did some stand freely while other fell? What techniques work best?*

Students will be timed during this activity to see who can build the tallest free-standing noodle structure that can support a marshmallow. This will teach students to learn as engineers through collaborating to design, test, and improve ideas as a team as well as examining the creative process of the final product. A project such as this could be related to the work of an architect or civil engineer. Both active subsets of the engineering profession that contribute to overall topic of STEM!

The city of Worcester has gotten the attention of the Boys & Girls Club and needs help from their members. Students will have 10 minutes to brainstorm and 18 minutes to construct a freestanding building. We want to petition for our building to be put in downtown Worcester, but only one design can be chosen! Let's see who can build the tallest freestanding structure with a teammate that can hold up the weight of a marshmallow.

Materials:

*All items should be placed in a paper bag so students cannot see before starting the brainstorm period

- Scissors
- 20 pieces of uncooked spaghetti (regular, not angel hair, or thin)
- 3 ft. of string that can be easily cut/broken
- 1 fresh marshmallow (not stale, mini, or jumbo)
- 3 ft. of masking tape
- Paper bags (standard lunch size)

For the Teacher:

- Create a 'marshmallow challenge kit' that contains all of your materials in a paper lunch bag so students are unable to see materials until they begin.
- Display the countdown clock somewhere for all students to see (i.e. Computer)
- Go through and carefully explain the rules numerous times and reinforce them by projecting them on a screen or somewhere students can see them.

Contest Rules:

*Challenge—build the tallest freestanding structure in just 18 minutes using nothing more than 20 sticks of spaghetti, one yard of tape, one yard of string, and one marshmallow. The marshmallow must be on top and cannot be deformed to hold it in place. The structure has to stand firmly on its own; it cannot be propped up, held, or suspended from the ceiling.

Marshmallow Design Student Quick Sheet:

Contest Rules:
*Challenge—build the tallest freestanding structure in just 18 minutes using nothing more than 20 sticks of spaghetti, one yard of tape, one yard of string, and one marshmallow. The marshmallow must be on top and cannot be deformed to hold it in place. The structure has to stand firmly on its own; it cannot be propped up, held, or suspended from the ceiling.

Rules:

- Build the tallest *freestanding* structure—the winning team is the one that has the tallest structure (measured by measuring stick). It will be measured from tabletop surface to the top of the marshmallow
- The ENTIRE marshmallow must be on the top—this means you cannot cut or eat any of the marshmallow or your team will be disqualified
- Use as much or as little of the kit
- You ARE ALLOWED TO break the spaghetti and cut up the tape or string
- The challenge is ONLY 18 minutes and you will have to stop when the time is up

Suspension Bridge Building Teacher Quick Sheet:

Introduction:

Bridges are structures which carry people and vehicles across natural or man-made obstacles. There are many types of bridges. Based on the length of the barrier to be crossed, the amount and type of traffic as well as forces of nature (wind, tide, flood) different materials and shapes of bridges are used.

In this lesson, your team has been tasked with building a bridge across Lake Quinsigamond. For this task, you will be building the strongest of all the bridge structures - a suspension bridge. Since this bridge will be regularly used, it must withstand substantial weight. Once each group has completed their bridge, the integrity of the structure will be tested by placing weights on the bridge. Whose bridge will hold more weight?

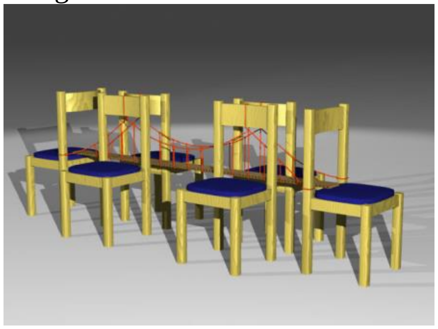
Materials:

- Safety scissors (for cutting stringers)
- Masking tape (optional, for attaching stringers to deck)
- Stapler with staples (optional, for attaching stringers to deck)
- 3-5 pound weights
- Two 15-foot pieces of rope (for cables)
- One 50-foot piece of string (for stringers/hangers)
- One 6-foot by 4-inch piece of cardboard (deck)
- 6 chairs (2 for each tower and 2 for anchors)

(*Note*: this is a list of materials per group)

Procedure:

- Arrange six chairs as in the diagram below:



- You and your teammates must figure out how to build the bridge. You are not allowed to anchor the deck, only the cables.
- Test your bridge by putting the weights in several different locations on the bridge. If your bridge supports the weight, congratulations!
- If you have extra time, put the weight in the middle of the bridge and start cutting the cables until the bridge collapses.

Suspension Bridge Building Student Quick Sheet:

Objective:
Students will build a model of a suspension bridge and test the amount of weight that it will support.

Procedure:

- Arrange six chairs as in the diagram below:

- You and your teammates must figure out how to build the bridge. You are not allowed to anchor the deck, only the cables.
- Test your bridge by putting the weights in several different locations on the bridge. If your bridge supports the weight, congratulations!
- If you have extra time, put the weight in the middle of the bridge and start cutting the cables until the bridge collapses.

Unit 4: Materials List

Lesson 1: Introduction to Sounds and Pitches

Materials:

- Plastic and wooden rulers (1 per student)
- Stop watch (1 per student)
- Scissors
- Straws

Lesson 2: Build a Band

Materials:

- Duct tape & Scotch tape
- Scissors & Staplers
- Pencils (at least 4 per student)
- Straws
- Craft sticks (4 per student)
- Rubber bands (2 mediums, 2 thin per student)
- Shoeboxes (1 per student)

Lesson 1: Introduction to Sounds and Pitches

(Physical Science, Energy, Waves)

Time: 20-30 Minutes
Group Size: Individual

Introduction:

Sound energy is the energy produced when sound is created. Today we are going to talk mainly about two characteristics of sound energy, pitch and frequency. Everyone make a quick sound. Did you notice some were higher and some were lower? This characteristic of sound is called *pitch*. Does anyone know what *frequency* is? It's the number of *vibrations* for each sound pitch. High-pitched sounds have faster frequencies or more vibrations than low-pitched sounds with slow frequencies. This can be seen in wave formations.

How do we use sound? We use sound to communicate, or like listening to music! Engineers also listen to sounds and create machines that detect sounds that our ears cannot even hear! Our ears pick up a wide range of frequencies. However, some animals hear frequencies that are too high-pitched or low-pitched for human hearing. These frequencies are called ultrasounds and infrasonic sounds.

Engineers design other instruments that take pitch and frequency in consideration. Ultrasounds are used a lot in medical equipment, especially in devices that help us view what we cannot normally see. NASA engineers are even developing medical instruments that help people diagnose injuries in space. Today, we are going to look at sound energy and how changing the length of an object changes its pitch and frequency. Are you ready to make some noise?

Opening Discussion Points/ Questions (if necessary):

- What do we use sound for, and why would we measure it?
- What are ultrasounds used for?
    - *It could also be to look at injuries (besides looking at a baby)*

Materials for Ruler Activity:

- Plastic and wooden rulers (1 per student)
- Stop watch (1 per student)

Materials for Straw Kazoo Activity:

- Scissors
- Straws

For the Teacher Procedure (Ruler activity):

- *Remind students that if they break their ruler on purpose they will not get another one*
- Create a discussion based on the difference between plastic and wood rulers. What would make the vibrations differ?
- Ask the students to fill out their chart

Procedure (For the Student):

1. Hold the ruler tightly to the table and hit the other end. Observe how the number of vibrations changes if you change how much the ruler extends past the table edge.

2. Continue doing this, and pull the ruler out more and more each time.
3. Fill out your chart with the number of vibrations. *What happens when you move the ruler out?*
4. What is the difference between the wooden and plastic rulers?

Distance of Ruler Beyond the Edge (in cm)	**Number of Vibrations (How many sec. does the ruler vibrate?)**

For the Teacher Procedure (Straw Kazoo Activity):

- Pass out straws and scissors to the children
- Ask students to cut one edge of the straw cutting one end to a point
- Tell them to blow through the straw and then cut a bit off the end to make it a little shorter
- Ask the students to observe the change in pitch as it is shortened
- Recall that *pitch* is the highness and lowness of a sound, and *frequency* is the rate of vibration in the pitch. So, slow vibrations = low pitch, high vibrations = high pitch.

Conclusion/ Closing Discussion Points:

- What happens to the frequency and pitch of the sound the ruler makes as you extend more of it off the table edge?
- What did cutting the straw do?
- How would you show a low pitch or low frequencies in waves?

Objectives/Outcomes:

- Students are able to define pitch and frequency.
- They can describe a sound with a high or low pitch and frequency.
- They can describe and show how to change the pitch of a sound.
- Students are able to give an example how engineers use pitch and frequency in the design of new products.

Common Core:

- Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. (Grade 4-8)
- Various relationships exist between technology and other fields of study. (Grades 3 - 6)

Next Generation Science Standards:

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)
- A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

Inspired by: PBS Design Squad Educator Resources (http://pbskids.org/designsquad/games/string_thing/)

Lesson 2: String-it Together

***(**Physical Science, Energy, Waves)*

Time: 1 hour
Groups: Individual

Introduction (10 min):

Build this lesson off of the previous lesson. Continue the discussion of pitch and frequency, but ask how you would begin to change these. Have students touch the front of their throats and say something. You can begin a discussion with a talk about vibration, and ask the students how the vibrations play a role in the creation of sound.

Discuss the terms *tension, gauge, and length* to assess the understand the definition the students have for the words before the activity (the can be discussed again afterward as a form of evaluation)

Opening Discussion:

- How do your vocal chords feel as you change the pitch? (Make them go high to low)
    - *(Vocal cords tighten to produce higher-pitched sounds and relax to produce lower-pitched ones. They also vibrate at a higher frequency for higher pitches.)*
- Can you name me some stringed instruments?
    - *(Guitar; ukulele; violin; cello; bass; mandolin; banjo; harp; piano; zither; dulcimer, etc.*)
- What is tension? How does this play a role on the strings?
- How do you 'gauge' sound?
    - *Think about how you would tune a guitar's strings*

Tell them their challenge. They have one night to put together a band to play a show at Hanover Theater. It's for an improv show that requires all instruments to be hand made. All of you need to create your own instrument to be played at tonight's show, and we will compare at the end!

- What are some of the things you'll need to figure out as you make your instrument? *(What box to use; what side of the box to put the rubber bands on; how to make strings out of rubber bands; how to attach the strings; how to tune the strings; how to make the instrument loud)*

Materials:

- Duct tape
- Scotch tape
- Scissors
- Pencils (at least 4 per student)
- Straws
- Craft sticks (4 per student)
- Rubber bands (2 mediums, 2 thin per student)
- Shoeboxes (1 per student)

For the Teacher Procedure:

1. Gather materials together before students come in, and try to keep them covered so students cannot see them before the beginning of the activity.
2. Have the students begin a brainstorming process by gathering their materials and asking, "Can you make a stringed instrument that you can tune and play?"
3. Give them a blank sheet to brainstorm ideas with materials on the table
4. Only tell them that using the rubber bands will become the strings (but make sure to keep them free so they can be played on your instrument)
5. Have them brainstorm ways to keep the shoe box from interfering with the 'strings' of your instrument?
6. Now, have them brainstorm ways to make your instrument sound different by changing something…find ways to tune a rubber band.
7. At the end, tell them to pair up and play a tune together with peers

Concluding/Closing Discussion:

- What causes different pitches?
    - *(Things vibrating at different frequencies)*
- What can affect a string's pitch?
    - *(Its length, tension, and gauge)*
- How did the rubber band's thickness affect its pitch?
    - *(With tension and length equal, a thicker rubber band will produce lower pitch than a thinner one will.)*

Conclusion:

Music and sound are both extremely important in many of our lives! There will always be a need for people with a musical ear. Just like engineers use ultrasound and sound wave techniques to test the machines (to see if they're broken), artists and singers use the concepts of *pitch* and *frequency* to change the sound of their voices! STEM topics can be found in any of the things we do throughout our day, just like listening to music. So, the next time you go home, look around and see what you might have laying around that can be transformed into your next instrument!

Activity Extension:

- Since this is an individual activity, you can now have the students play their instruments together. This can be done in two ways:
    - Students can form groups and make bands (Optional: make names and perform for each other)
    - Students could each have a turn to play their instrument and compare
    - Have them try: *Happy Birthday, We Will Rock You, TV show theme songs, anything they may know*

Common Core:

- Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. (Grade 4-8)
- Various relationships exist between technology and other fields of study. (Grades 3 - 6)

<u>Next Generation Science Standards:</u>

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)
- A sound wave needs a medium through which it is transmitted. (MS-PS4-2)
- Apply scientific ideas or principles to design an object, tool, process or system. (MS-PS2-1)

<u>For the Teacher (troubleshooting):</u>

Hearing:

- Try to keep the room as quiet as possible when students are testing out their instruments
- Remove anything that may interfere with the vibration of the strings such as excess tape

Tuning:

- To lower the pitch—stretch out the rubber band making it longer
- Raising or lowering the height of the bridge (pencils/straws) will change tension and increase or decrease pitch
- Tighten the rubber bands by re-adjusting the rubber band on the box

Playing a song:

- Remind the students that 'fretting' the string, pushing it down or pinching it, will change the pitch of the string
- Have them try: *Happy Birthday, We Will Rock You, TV show theme songs, anything they may know*

Inspired by: PBS Design Squad Educator Resources (http://pbskids.org/designsquad/games/string_thing)

Sounds of STEM Introduction Teacher Quick Sheet

Objectives: Students are able to define pitch and frequency through a series of activities. Students are able to describe and exhibit change of sound through their own personal instruments in the later activity.

Introduction:

Today we are going to talk mainly about two characteristics of sound energy, pitch and frequency. Everyone make a quick sound. Sounds are higher and lower. This characteristic of sound is called *pitch*. Does anyone know what *frequency* is? It's the number of *vibrations* for each sound pitch. High-pitched sounds have faster frequencies or more vibrations than low-pitched sounds with slow frequencies. *How do we use sound?* We use sound to communicate, or like listening to music! Engineers also listen to sounds and create machines that detect sounds that our ears cannot even hear! Today, we are going to look at sound energy and how changing the length of an object changes its pitch and frequency. Are you ready to make some noise?

Opening Discussion Points/ Questions (if necessary):

- What do we use sound for, and why would we measure it?
- What are ultrasounds used for?
    - *It could also be to look at injuries (besides looking at a baby)*

Materials:

- Plastic and wooden rulers (1 per student)
- Stop watch (1 per student)
- Scissors
- Straws

For the Teacher Procedure (Ruler activity):

- *Remind students that if they break their ruler on purpose they will not get another one*
- Create a discussion based on the difference between plastic and wood rulers. What would make the vibrations differ?
- Ask the students to fill out their chart

For the Teacher Procedure (Straw Kazoo Activity):

- Pass out straws and scissors to the children
- Ask students to cut one edge of the straw cutting one end to a point
- Tell them to blow through the straw and then cut a bit off the end to make it a little shorter
- Ask the students to observe the change in pitch as it is shortened
- Recall that *pitch* is the highness and lowness of a sound, and *frequency* is the rate of vibration in the pitch. So, slow vibrations = low pitch, high vibrations = high pitch.

Conclusion/ Closing Discussion Points:

- What happens to the frequency and pitch of the sound the ruler makes as you extend more of it off the table edge?
- What did cutting the straw do?
- How would you show a low pitch or low frequencies in waves?

Sounds of STEM Introduction Student Quick Sheet:

Procedure (For the Student):

1. Hold the ruler tightly to the table and hit the other end. Observe how the number of vibrations changes if you change how much the ruler extends past the table edge.
2. Continue doing this, and pull the ruler out more and more each time.
3. Fill out your chart with the number of vibrations. *What happens when you move the ruler out?*
4. What is the difference between the wooden and plastic rulers?

Distance of Ruler Beyond the Edge (in cm)	**Number of Vibrations (How many sec. does the ruler vibrate?)**

Build a Band Teacher Quick Sheet

<u>Introduction (10 min):</u>

Build this lesson off of the previous lesson. Continue the discussion of pitch and frequency, but ask how you would begin to change these. Have students touch the front of their throats and say something.

<u>Opening Discussion:</u>

Tell them they have one night to put together a band to play a show at Hanover Theater. It's for an improv show that requires all instruments to be hand made. All of you need to create your own instrument to be played at tonight's show, and we will compare at the end!

- How do your vocal chords feel as you change the pitch? (Make them go high to low)
    - *(Vocal cords tighten to produce higher-pitched sounds and relax to produce lower-pitched ones. They also vibrate at a higher frequency for higher pitches.)*
- Can you name me some stringed instruments?
    - *(Guitar; ukulele; violin; cello; bass; mandolin; banjo; harp; piano; zither; dulcimer*)
- How do you 'gauge' sound? What is tension on the strings?
    - *Think about how you would tune a guitar's strings*
- What are some of the things you'll need to figure out as you make your instrument? *(What box to use; what side of the box to put the rubber bands on; how to make strings out of rubber bands; how to attach the strings; how to tune the strings; how to make the instrument loud)*

<u>Materials:</u>

- Duct tape & Scotch tape
- Scissors & Staplers
- Pencils (at least 4 per student)
- Straws
- Craft sticks (4 per student)
- Rubber bands (2 mediums, 2 thin per student)
- Shoeboxes (1 per student)

<u>For the Teacher Procedure:</u>

1. Gather materials together before students come in, and try to keep them covered so students cannot see them before the beginning of the activity.
2. Have the students begin a brainstorming stringed instrument and give them a blank sheet to brainstorm ideas telling them the materials (Only tell them that using the rubber bands will become the strings)
3. At the end, tell them to pair up and play a tune together with peers

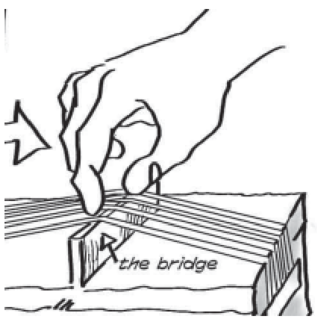
<u>Concluding/Closing Discussion:</u>

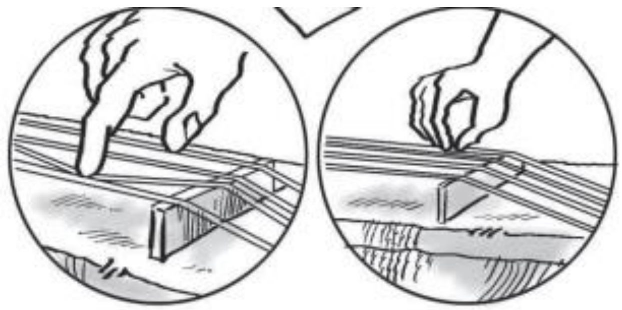
- What causes different pitches? *(Things vibrating at different frequencies)*
- What can affect a string's pitch? *(Its length, tension, and gauge)*
- How did the rubber band's thickness affect its pitch?
    - *(With tension and length equal, a thicker rubber band will produce a lower pitch than a thinner one will.)*

Build a Band Student Quick Sheet

<u>Things/Ideas to Keep in Mind:</u>

- Rubber bands can be kept in loops, or could be cut into strips!
- Did you take the lid off of your shoe box?
    - Will the rubber bands go over a closed or open surface?
- The box OR lid could be your instrument!
- Pressing or pinching the string changes length! (Mark where it should be stretched to)
- Think about making a bridge to keep your strings off the box!
    - Vibrations go from the string to the box! (don’t use too much tape)





Unit 5: Materials List

Lesson 1: Egg Drop

Materials:

- At least 8 Eggs (1 per student/group and 2 extra)
- Tape
- Hot glue
- Markers
- Trash bags or cheap table cloths - for covering the ground where the eggs will be dropped
- Recycled materials including:
  - Bubble wrap, plastic Easter eggs, parachute army men, paper towel/toilet paper rolls. saran/plastic wrap, plastic grocery bags, cardboard, printer/construction paper, latex balloons, craft sticks

(*Note:* Building supplies are necessary but any resources from our recommended list may be used, as well as any other recycled materials)

Lesson 1: The Egg Drop

(Engineering, Forces, Physics)

Time duration of lesson: 1:30 (10 minutes for opening discussion, 50 minutes for construction, 20 minutes for egg drop competition)
Group Size: individual if resources permit, pairs otherwise

Introduction:

A force is a push or pull motion between two or more objects. One of the biggest forces we face every day is the force of gravity. What is gravity? Gravity is a pulling force which holds us on the ground. Also, if something is thrown into the air, it is gravity which pulls it down to the ground.

Our task is to safely drop food and First Aid supplies to an area which has been recently hit by a natural disaster. In this case, the egg will represent the supplies, and we must build a structure which will prevent the egg from breaking.

Opening Discussion Points/ Questions:

- What are forces?
- How does a bounce-house help you jump and stop you from hurting yourself when you fall?
- How do you keep something from breaking when it falls?
- What are some things that fall from the sky in our culture and how do we stop them from crashing? (Ex: Mars rovers, parachutes, airplanes)

Materials:

Note: Building supplies are necessary but any resources from our recommended list may be used, as well as any other recycled materials.

- At least 8 Eggs (1 per student/group and 2 extra)
- Tape
- Hot glue
- Markers
- Trash bags or cheap table cloths - for covering the ground where the eggs will be dropped
- Recycled materials including:
  - Bubble wrap, plastic Easter eggs, parachute army men, paper towel/toilet paper rolls. saran/plastic wrap, plastic grocery bags, cardboard, printer/construction paper, latex balloons, craft sticks

For the Teacher Procedure:

- The materials can be given to the students in two different ways:
  - Split the materials evenly and give each student their share - the requires the teacher to split all materials before the students enter the room, and is best done if there are more than enough supplies for all students.
  - Prepare a supply table, where students can walk up to the table and grab some supplies, a few at a time. Note, keep some scissors at this table for cutting off pieces.

- Determine where the egg structures will be dropped. We suggest this location would be at least 8 feet high, though the higher it is, the more challenging this activity will be. This location can be anywhere from on top a ladder, from a stairwell, or off of a balcony. However, wherever the egg structures will be dropped must be protected by either plastic bags or a plastic table cloth laid on the ground, to make the cleanup process easier. Additionally, this area should be "roped off" to keep people around the competition from standing in this area.
- Additionally, as an optional activity, each of the students may be given time (5-10 minutes) at the beginning of their build period to decorate their egg and make it their own.
- During the construction period: allow students to experiment with the different resources and assist them in the building of their structures. Ask particular questions about the resources they are using and why they are using those, not others. Encourage them to use resources that they may not think of working.
- For the competition period: one by one, drop each egg structure from the designated dropping point, cleaning up after each drop if necessary.

<u>Procedure (For the Student):</u>

- Build a structure using the given materials to prevent an uncooked egg from breaking when it is dropped from a given height.
- You may use any of the given materials but are not required to use any particular one.

<u>Conclusion/ Closing Discussion Points:</u>

- Have the students discuss what worked with their contraptions and what didn't.
- How did the things that worked well counter the force of gravity on your structures?
- If you had unlimited time and resources, how would you change your structure?
- Discuss any related careers of the topics that came up during the activity. Examples include aeronautical (space) engineering, civil engineering

<u>Objectives/Outcomes:</u>

- Describe and define material properties.
- Identify the forces of gravity, drag, and the term air resistance

<u>Common Core:</u>

- Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. (Grade 6-8)
- Design involves a set of steps, which can be performed in different sequences and repeated as needed. (Grades 6 – 8)
- Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum. (Grades 6 -8)
- Identify appropriate problems for technological design. Students should develop their abilities by identifying a specified need, considering its various aspects, and talking to different potential users or beneficiaries. They should appreciate that for some needs, the cultural backgrounds and beliefs of different groups can affect the criteria for a suitable product. (Grades 5 - 8)

- Implement a proposed design. Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy. (Grades 5 - 8)

Next Generation Science Standards:

- *Physical Science, K-4, 5-8:* Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. (MS-PS2-4.)
- *Science and Technology, K-4, 5-8:* Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)

Inspired by: Teach Engineering Teacher Resources (https://www.teachengineering.org/view_activity.php?url=collection/cla_/activities/cla_egg_drop_activity1/cla_egg_drop_activity1.xml)

The Egg Drop Teacher Quick Sheet

Objectives: Have the students use engineering and problem solving to build a structure which will successfully prevent an uncooked egg from dropping from a designated height.

Materials:

- At least 8 Eggs (1 per student/group and 2 extra)
- Tape
- Hot glue
- Markers
- Trash bags or cheap table cloths - for covering the ground where the eggs will be dropped
- Recycled materials including:
    - Bubble wrap, plastic Easter eggs, parachute army men, paper towel/toilet paper rolls. saran/plastic wrap, plastic grocery bags, cardboard, printer/construction paper, latex balloons, craft sticks

Preparation:

Determine the location from which the eggs will be dropped. We recommend dropping from a height that is at least 8 feet tall, though higher works better. A ladder, balcony, or stairs may work.

Determine whether the students will be given individual packages with the given materials, or a materials table can be utilized. Then prepare either the packages or the table.

Opening Discussion:

What are forces? And how do they affect our daily lives? What happens to forces when something is dropped on the ground? How do we prevent dropped things from breaking?

Procedure:

1. Give the students a period of 45 minutes to build their structures
2. At the end of the build period, clean up all remaining supplies and clean up the room for the egg drop competition
3. For the egg drop competition:
    a. Set up the trash bags or plastic table cloths on the ground where the egg structures will be dropped in case of egg breakage.
    b. Have an adult drop the student's' structures to ensure that they are just dropped, not thrown up or down from the designated height
    c. Leave time in between the dropping of each structure to clean up if necessary
4. Optional - Give all students a reward or prize whether or not they won - to prevent students from coming out of the activity feeling like they failed.

Closer / Assessment:

- Have the students discuss what worked with their contraptions and what didn't.
- How did the things that worked well counter the force of gravity on your structures?
- If you had unlimited time and resources, how would you change your structure?

Unit 6: Materials List

Lesson 1: Flashlight Dissection

Materials:
- Cheap flashlights - dollar store quality (1 per group)
- Screwdrivers
- Blank paper
- Pencils or markers

Lesson 2: Chibitronics

Materials:
- Copper tape (at least 3 feet per student)
- Cell batteries (2 per student)
- Chibitronics LED stickers (3-6 per student)

Lesson 1: Flashlight Dissection

(Engineering, electronics)

Time duration of lesson: 20 minutes
Group Size: Teams of 2

Introduction:

Electricity is present in every part of our lives, from keeping our lights on, to charging phones, and even helping us keep food cold. A circuit is a loop of electricity from which appliances such as lights and refrigerators can gain the electricity they need to function correctly. However not all circuits require something to be plugged into a wall. The simplest of circuits have just a power source and an application like an LED. One such standalone circuit is found in a flashlight, where there is a battery and a light bulb. Our task is to "dissect", or take apart, the pieces of a flashlight to figure out what parts make up that circuit.

Opening Discussion Points/ Questions:

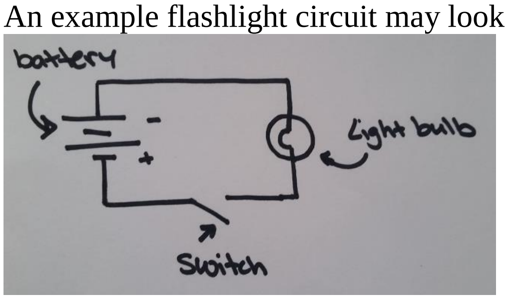
- What is electricity?
- How do we use electricity?
- What is a circuit?
- What are more circuits we use or can see?

Materials:

- Cheap flashlights - dollar store quality (1 per group)
- Screwdrivers
- Blank paper
- Pencils or markers

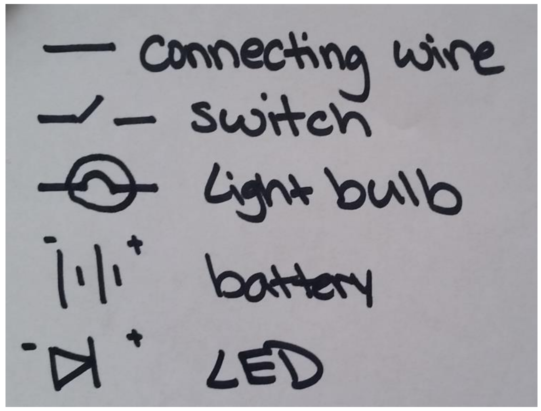
For the Teacher Procedure:

- This is an activity where the teacher should try to break down ("dissect") the flashlight beforehand to make sure they have the necessary screwdrivers or other tools necessary to complete this task.
- If not done already, print out the student Circuits handout for reference during the activity
- An example flashlight circuit may look like the following:



Procedure (For the Student):

1. Carefully take apart the flashlight using the tools provided
2. Pay close attention to the pieces which seem to have a part in the circuit
3. Draw the circuit using the given symbols (or make up your own!):



Conclusion/ Closing Discussion Points:

- An electrician is someone who works on the electrical units of people's buildings
- An electrical engineer works on other circuits, like using tiny circuit pieces to make hardware in your computer
- The different things that were in the flashlights could include: a light bulb, connecting wire, a battery, and a switch.

Objectives/Outcomes:

- Students are more aware of the presence of electricity and circuits all around them
- Students are introduced to the jobs of electrician and electrical engineer

Common Core:

- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem (Grade 6-8)

Next Generation Science Standards:

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)
- Models of all kinds are important for testing solutions. (MS-ETS1-4)

Developed by: Alexandra Bittle

Lesson 2: Chibitronics Circuit

(*Electronics)*

Resources: http://store.chibitronics.com/collections/all

Time duration of lesson: 45-50 minutes

Group Size: individual

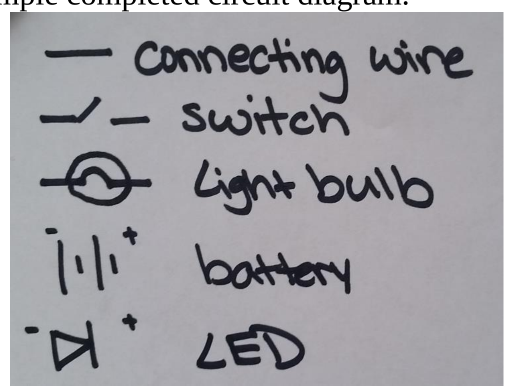
Introduction:

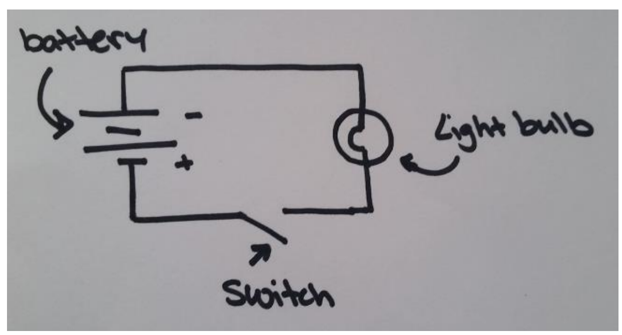
As we learned in our first activity, a circuit is a loop of electricity, which we can find in many different places and effect every part of our modern lives.

An LED - or Light Emitting Diode - is a kind of light that we can put inside circuits. They come in may come in different colors, and depending on the amount of power we have in our circuit, it can be bright or not. We will be using LED stickers, which have all the pieces we need. It is important to remember that the positive (+) end must point to the positive battery, and the negative (-) end must point to the negative battery.

Copper is a type of metal and is used frequently with circuits because it conducts electricity. We will be using it in a form of tape, so it is more fragile than most copper, but it still works for making circuits.

Examples of electronic symbols can be found in the following image along with an example completed circuit diagram.





Materials:

- Copper tape - at least 3 feet per student
- Cell batteries - 2 per student
- Chibitronics LED stickers - 3-6 per student

For the Teacher Procedure:

- Print out the student circuit handout if not done already
- Have the students draw a circuit diagram before creating anything with the circuitry components.
- Each circuit must include:
    - A positive- marked battery
    - A negative- marked battery
    - LED's in the correct direction (triangle pointed towards negative battery)
    - Only one loop in the copper tape - no tape intersections

An example circuit:

Procedure (For the Student):

- Draw out a shape (any shape that does not have any crosses - only one loop) in pencil
- Add where you want LED's (lights) to be put
- Add where you want the batteries to go
    - Make sure the two batteries are in a place where the paper can be folded in half to connect them
- Draw the LED and battery symbols where you plan on putting them
- Have your instructor look over your drawing to make sure you can build your circuit
- Once you have approval, add copper tape to all the connecting lines, making sure to not cut the tape in the corners, but make a corner in the tape
- Put in the two batteries, making sure the flat side is on the positive edge of your copper tape, and the non-flat side on the negative side of your tape
- Finally add your LED stickers
- Use a binder clip to hold the two batteries together and complete your circuit!

Conclusion/ Closing Discussion Points:

- Discuss what was hard or easy about designing circuits
- What would you build if you had unlimited stickers and tape?

Objectives/Outcomes:

- Students are better able to recognize the presence of electronic circuits
- Student become comfortable and confident in their ability to build simple circuits

Common Core:

- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem (Grade 6-8)
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (Grade 6-8)

Next Generation Science Standards:

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3)
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MSETS1-4)
- Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)

Developed by: Alexandra Bittle

Flashlight Dissection Activity Teacher Quick Sheet:

<u>Objectives:</u>

- Each student will think of the ways that electricity and circuits affect their lives/many things they use that contain circuits
- Each group will "dissect" a flashlight or related item to observe the circuit inside

<u>Materials</u>:

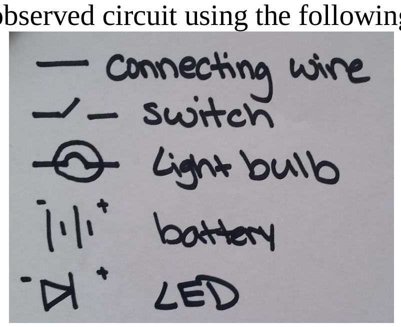
- Cheap flashlight or related small circuit item - 1 per team of 2
- Screwdrivers

<u>Opening Discussion Points:</u>

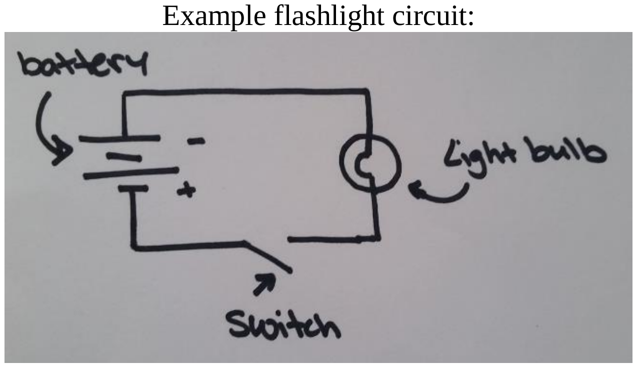
- How electricity affects their day to day life
- Electricity works in loops - aka circuits
- Example standalone circuits - flashlights, phones, remote control cars

<u>Procedure</u>

1. Print out a student Circuit handout for each student if not done already
2. Give each pair of students a flashlight (or related standalone circuit object)
3. Instruct each group to take apart the flashlight to observe how the circuit inside works
4. Have each group draw the observed circuit using the following symbols:



Example flashlight circuit:



<u>Closing Discussion Points:</u>

- Have each group present their circuit diagrams
- Small discussion regarding any differences between diagrams

Chibitronics Circuits Lesson Teacher Quick Sheet

Objectives: Using the basic knowledge the students gained through the flashlight activity, have the students build a new circuit on their own using the Chibitronics material

Opening Discussion:

- Discuss copper tape, LED's, electricity

Materials:

- 2 Cell batteries per student
- At least 3 feet of copper tape per student
- at least 3 LED stickers per student

Preparation:

- Have the students draw a circuit diagram before creating anything with the circuitry components.
- Each circuit must include:
    - A positive- marked battery
    - A negative- marked battery
    - LED's in the correct direction (triangle pointed towards negative battery)
    - Only one loop in the copper tape - no tape intersections

Procedure (Also in the student handout):

1. Draw out a shape (any shape that does not have any crosses - only one loop) in pencil
2. Add where you want LED's (lights) to be put
3. Add where you want the batteries to go
    a. Make sure the two batteries are in a place where the paper can be folded in half to connect them
4. Draw the LED and battery symbols where you plan on putting them
5. Have your instructor look over your drawing to make sure you can build your circuit
6. Once you have approval, add copper tape to all the connecting lines, making sure to not cut the tape in the corners, but make a corner in the tape
7. Put in the two batteries, making sure the flat side is on the positive edge of your copper tape, and the non-flat side on the negative side of your tape
8. Finally add your LED stickers
9. Use a binder clip to hold the two batteries together and complete your circuit!

Closer / Assessment:

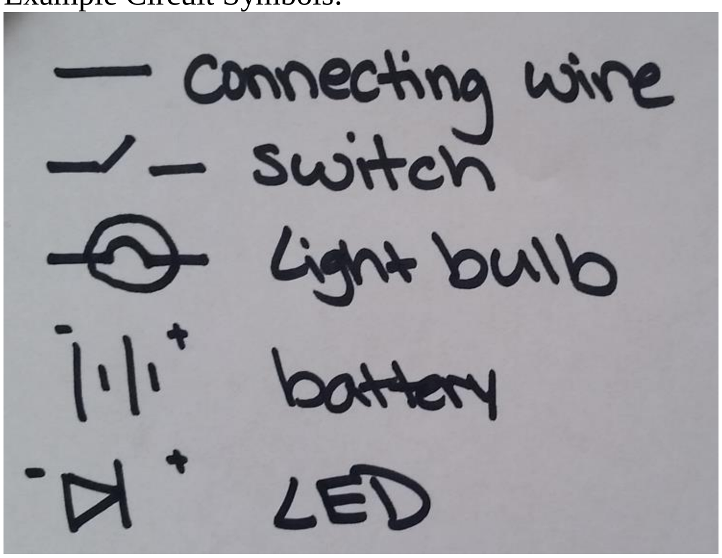
- Have each student present their creations and explain what worked well or what didn't
- Ask the students about their favorite and least favorite parts of this activity/unit

Chibitronics Circuits Student Quick Sheet

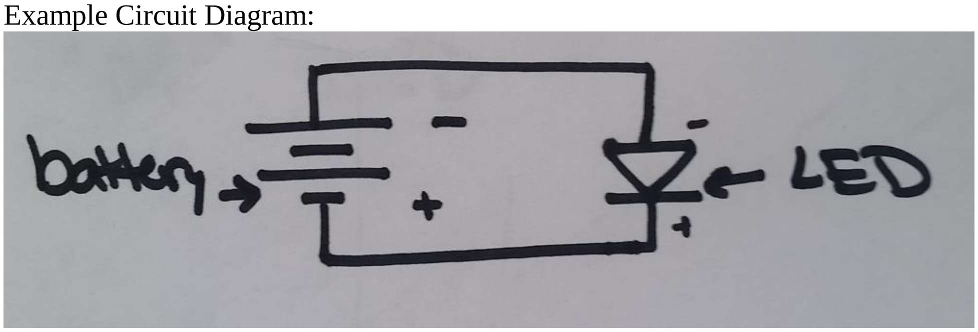
Procedure:

1. Draw out a shape (any shape that does not have any crosses - only one loop) in pencil
2. Add where you want LED's (lights) to be put
3. Add where you want the batteries to go
    a. Make sure the two batteries are in a place where the paper can be folded in half to connect them
4. Draw the LED and battery symbols where you plan on putting them
5. Have your instructor look over your drawing to make sure you can build your circuit
6. Once you have approval, add copper tape to all the connecting lines, making sure to not cut the tape in the corners, but make a corner in the tape
7. Put in the two batteries, making sure the flat side is on the positive edge of your copper tape, and the non-flat side on the negative side of your tape
8. Finally add your LED stickers
9. Use a binder clip to hold the two batteries together and complete your circuit!

Example Circuit Symbols:



Example Circuit Diagram:



Unit 7: Materials List

Lesson 1: Skewer Through a Balloon

Materials:

- Latex balloons (2 per student)
- Wooden cooking skewer (2 per student)
- Cooking oil (1 container per class)
- Sharpie pen/marker (1 per student)

Lesson 2: Make Your Own Ice Cream

Materials:

- Small zip-lock zipper style bags (1 per student)
- Gallon zip-lock zipper style bags (1 per student)
- ½ cup milk (per student)
- 1 tablespoon sugar (per student)
- ½ teaspoon vanilla extract (per student)
- 4 tablespoons of Kosher rock salt (per student)
- 2+ cups ice cubes (per student)
- Liquid measuring cups
- Measuring spoons
- Measuring Cups or scoops
- Paper Towels
- Lesson Handouts
- Large cooler (to keep items cold)
- Rags or hand towels to cover ice-cream bags when shaking
- Plastic spoons

Lesson 1: Skewer Through a Balloon

(Physical Science)

Time: 15-20 Minutes
Group Size: Individual

Introduction:

In this lesson we are going to do our best to get this skewer through our balloons! By taking your wooden skewers, I want all of us to blow up our balloons and attempt to get the skewer completely through the balloon. This may seem a little crazy, but we will have to test out the experiment ourselves! Before we begin we need to make our first scientific hypothesis so, do you think the balloon will pop? Or is it possible to push the skewer through and through?

Materials:

- Latex balloons (2 per student)
- Wooden cooking skewer (2 per student)
- Cooking oil (1 container per class)
- Sharpie pen/marker (1 per student)

Procedure:

1. The first step is to inflate the balloon until it's almost nearly full size and then let out about ⅓ of the air. Tie a knot at the end of the balloon. The balloon should be smaller than the length of the skewers.
2. Examine the balloon and try to find an area where you can push the skewer through
3. You can try to dip the wooden skewer into the cooking oil, which can act as a sealant.
4. Be careful not to prick yourself or the balloon with the skewer!

For the Teacher:

1. If students are unable to do the task it is likely because they are putting the skewer in the wrong way. Give students a new balloon and a marker. Have the following discussion before showing the correct way. This will assess understanding of the stress placed on the balloon:
2. Tell students to blow up the new balloon, and use the Sharpie pen/marker to draw about 10-15 dots on the balloon. The dots should be about the size of a head of a match. Be sure to draw them at both ends and in the middle of the balloon.
3. Inflate the balloon halfway and tie at the end. Observe the various sizes of the dots all over the balloon.
    a. Where are the dots on the latex molecules stretched out the most?
    b. Where are they stretched out the least?
4. Dip the wooden skewer in the vegetable oil and use your fingers to coat the skewer with oil.
5. Use the observations that you made previously about the dots on the balloon to decide the best spot to put the balloon with the skewer.
6. Have the students place the sharpened tip of the skewer on the thick end of the balloon and push the skewer into the balloon. Just use gentle pressure (and maybe a little twisting motion) to puncture the balloon.

7. Push the skewer all the way through the balloon until the tip of the skewer touches the opposite end of the balloon (other thick portion). Keep pushing until the skewer penetrates the rubber.
8. Gently remove the skewer from the balloon when you are done!

For the Student (*Can be printed or discussed):

1. Take your first balloon and blow it up as much as you can (without popping it), and release a little bit of air so that you can tie it
2. Tie the balloon at its ends
3. Take your skewer and choose a spot on the balloon to push it all the way through!
4. It's okay if you pop your first try! You will have more chances.
5. Take your second balloon from your teacher, and a marker
6. Put small marker dots all over the balloon (like the size of a tic-tac)
7. Follow the teacher's instructions!

Conclusion:

There is a little secret behind being able to put the skewer through the balloon. The secret is in finding the part of the balloon where the molecules are under the least amount of stress or strain. After you all drew on the balloon with the marker, you should have been able to see where the dots were smaller and larger. The small parts were your areas of less stress, and those were found on the ends of the balloon. When the point of the skewer is positioned at the ends of the balloon, the solid object passes through the inflated balloon without popping it.

If you could see the rubber that makes up a balloon under a microscope, you would see many long strands or chains of molecules. These long strands of molecules are called *polymers*, and the polymer chains are so elastic that it allows the rubber to stretch. Even before drawing the dots on the balloon, you probably noticed that the middle of the balloon stretches more than either end. Therefore, to get it through you have to pierce the balloon at a point where the molecules are the least stretched out! However, the molecules around the holes you made that stretched around the skewer, were so tight that they were able to keep the air inside the balloon instead of rushing out.

For engineers, this a way for them to understand the stress and tension placed on certain objects. Before the begin construction, designing, or building, engineers must understand the stress of their materials to make sure they can withstand the pressure!

Objectives/Outcomes:

- Students are able to begin developing hypotheses based on previous knowledge, and test their hypotheses
- Students are able to explain to their peers the phenomena and the discussion behind it
- The discussions of polymers and tension coincide with the common core expectancies of science courses in grades 6 through 8.
- Students are encouraged to test this out at home and have their parent's perform a taste test as well.

Common Core:

- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events. (Grades 6-8)]

Next Generation Science Standards:

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2), (MS-PS2-4)

Inspired by: Steve Spangler Science Experiments (http://www.stevespanglerscience.com/lab/experiments/skewer-through-balloon/)

Lesson 2: Make-your-own Ice Cream

(Physical sciences, earth science, life science, and chemistry)

Time: 1 hour (20 minute clean up)
Group Size: Individual

Introduction:
Acting as physicist, chemist, and engineers, students will investigate the ways in which ice-cream begins as a liquid and morphs into a solid student's will first understand shifting qualities.

Opening Discussion Points:

- To get the students interest in understanding the breadth of STEM disciplines, start with a class activity by a whiteboard or poster board. Ask the children what they believe scientists do by simply asking "What do you think a scientist does?", and record the responses (children are encouraged to write words and draw pictures). Allow students to brainstorm alone, then as a team.
  - Give examples:
    - Scientists are trying to save polar bears and honey bees from becoming extinct
    - Scientist use zombies as a model for understanding the spread of contagious diseases.
    - Scientists use robots that might one day be able to do your chores!
    - Scientists are discovering new planets and stars as we speak
    - Scientists are designing life suits that simulate what it feels like at any age of your life
    - Scientist…. make the ice-cream you eat!!

Materials:

- Small zip-lock zipper style bags
- Gallon zip-lock zipper style bags
- ½ cup milk (per student)
- 1 tablespoon sugar
- ½ teaspoon vanilla extract
- 4 tablespoons of Kosher rock salt
- 2+ cups ice cubes
- Liquid measuring cups
- Measuring spoons
- Measuring Cups or scoops
- Paper Towels
- Lesson Handouts
- Large cooler (to keep items cold)
- Rags or hand towels to cover ice-cream bags when shaking
- Plastic spoons

For the Teacher Procedure:

1. Get the students engage and continue the scientific trend of conversation. Before taking out supplies, hand out the "What Do You Know About Ice-Cream" handout OR have a discussion about the following:
    a. What is everyone's' favorite ice-cream?
    b. What ingredients go into making ice-cream
        i. Hold up ingredients to show they are right!
        ii. Ask what the salt is for?
    c. This will get the children discussing hypotheses –also ask the children whether the ingredients are a liquid, solid, or gas?
        i. How do we start with liquids and end with solids?
2. Have the students, in groups, brainstorm ways they think they end up with a solid. (Is it mystery chemicals? Elsa? Unknown forces? science?)
3. Pass out the "Let's experiment with Ice-cream" handout—give extras for students recording more than one bag
4. Pass out the 'recipe sheet'
5. Once the students have completed their trial runs, have then complete the steps again! Encourage students to change at least one ingredient and record/observe their results
6. On their worksheets—have the students describe their ice-cream based on: taste, smell, and any senses. Were the batches different? How does it compare to store brand?

For the Student

1. Get small Ziploc bag and label it with your name
2. Add ½ cup of milk
3. Add ½ teaspoon of vanilla extract
4. Add 1 tablespoon of sugar
5. Seal your Ziploc bag and leave as little air as possible
6. Place the smaller bag inside of the Gallon Ziploc bag
7. Cover the small bag with ice, filling your whole gallon bag
8. Add 4 tablespoons of the Kosher salt to the top of the ice
9. Get all of the air out of the bag and wrap your bag in a hand towel
10. Shake, roll, or move the bag around for a full 8-10 minutes (making sure the ice is still covering the milk mixture bag)
11. Change at least one ingredient to see if it changes the final result.
12. On your sheets—describe your ice-cream based on: taste, smell, and any senses. What was the difference between your batches? How does it compare to your favorite ice cream?

Closing Discussion Points:

As the students eat their work have them talk about their findings. This means have them discuss the ingredients they used, and what might happen if you change those. *How did we end up with frozen ice-cream?* The answer comes from the student's understanding of matter. The ice (solid) absorbs energy causing it to melt going into a liquid.

- Ask the students where energy comes from! (*In this case, the energy comes from anything touch the ice cubes!)*

By adding the salt, we are able to stop the melting process. Salt lowers the freezing point of the ice making the cold ice—colder. This allows the milk to freeze while shaking the bag before the ice melts! (What temp. does water freeze?! 32 degrees Celsius) By adding salt we created a cold enough environment.

Objectives/Outcomes:

- Much deeper understanding of the STEM disciplines and what a 'scientist' does. This is seen in breaking the 'lab coat' stereotype as children would be able to show progress in the understanding of the vastness of the STEM disciplines.
- Students discuss matter and the change of matter based on chemical reactions
- The discussions of dissolving and content matter coincide with the common core expectancies of science courses in grades 6 through 8.
- Students are encouraged to test this out at home and have their parent's perform a taste test as well.
- Most importantly, the thrill of discovering and curiosity of an unknown phenomena will be what leads children to further interest in the future.

Common Core:

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (Grade 6-8)
- Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena (Grade 6-8)
- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events. (Grade 6-8)
- Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion. (Grade 6-8)

Next Generation Science Standards:

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3)
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

Skewer Through Balloon Teacher Quick Sheet

Opening Discussion:

In this lesson we are going to do our best to get this skewer through our balloons! By taking your wooden skewers, I want all of us to blow up our balloons and attempt to get the skewer completely through the balloon. *Do you think the balloon will pop?* This may seem a little crazy, but we will have to test out the experiment ourselves! Before we begin we need to make our first scientific hypothesis so, do you think the balloon will pop? Or is it possible to push the skewer through and through?

Preparation for the Teacher:

1. If students are unable to do the task it is likely because they are putting the skewer in the wrong way. Give students a new balloon and a marker. Have the following discussion before showing the correct way. This will assess understanding of the stress placed on the balloon:
2. Tell students to blow up the new balloon, and use a Sharpie to draw about 10-15 dots on the balloon. Be sure to draw them at both ends and in the middle of the balloon.
3. Inflate the balloon halfway and tie at the end. Observe the various sizes of the dots all over the balloon.
    a. Where are the dots on the latex molecules stretched out the most?
    b. Where are they stretched out the least?
4. Dip the wooden skewer in the vegetable oil and use your fingers to coat the skewer with oil.
5. Have them decide the best spot to put the balloon with the skewer
6. Have the students place the sharpened tip of the skewer on the thick end of the balloon and push the skewer into the balloon. Just use gentle pressure (and maybe a little twisting motion) to puncture the balloon.
7. Push the skewer all the way through the balloon until the tip of the skewer touches the opposite end of the balloon (other thick portion). Keep pushing until the skewer penetrates the rubber.
8. Gently remove the skewer from the balloon when you are done!

Closing Discussion:

There is a little secret behind being able to put the skewer through the balloon. The secret is when you find the parts of the balloon that have the least amount of stress or strain. Where would those spots be? The smaller dots on your balloon show areas of less stress, and those were found on both ends of the balloon! Under a microscope, you would see many long strands/chains of molecules that are called *polymers*. These polymers are so elastic that it makes the rubber stretch, but to be able to pierce through the balloon we pierce through the stretchy polymers!

For engineers, this is a way that they might understand stress and tension, just like when we tested the strength of our marshmallow towers! During the designing process, and before building, engineers must understand the stress of the materials they are using!

Make Your Own Ice-cream Teacher Quick Sheet

(Physical sciences, earth science, life science, and chemistry)

Opening Discussion Points:

- Ask the children what they believe scientists do by simply asking "What do you think a scientist does?", and record the responses.
    - Give examples:
        - Scientists are trying to save polar bears and honey bees from becoming extinct
        - Scientist use zombies as a model for understanding the spread of contagious diseases.
        - Scientists use robots that might one day be able to do your chores!
        - Scientists are discovering new planets and stars as we speak
        - Scientists are designing life suits that simulate what it feels like at any age of your life
        - Scientist…. make the ice-cream you eat!!
- Ask these questions:
    - What is everyone's' favorite ice-cream?
    - What ingredients go into making ice-cream
        - Hold up ingredients to show they are right!
        - Ask what the salt is for?
        - How do we start with liquids and end with solids?

For the Teacher:

- Pass out the 'recipe sheet'
- Once the students have completed their trial runs, have then complete the steps again! Encourage students to change at least one ingredient and record/observe their results. On their worksheets—have the students describe their ice-cream based on: taste, smell, and any senses. Were the batches different? How does it compare to store brand?

Materials:

- Small zip-lock zipper style bags
- Gallon zip-lock zipper style bags
- ½ cup milk (per student)
- 1 tablespoon sugar
- ½ teaspoon vanilla extract
- 4 tablespoons of Kosher rock salt
- 2+ cups ice cubes
- Liquid measuring cups
- Measuring spoons
- Measuring Cups or scoops
- Paper Towels
- Recipes Sheet
- Large cooler (to keep items cold)
- Rags or hand towels to cover ice-cream bags when shaking
- Plastic spoons
- Any toppings (chocolate sauce, sprinkles, etc.)

Concluding Discussion:

- Who can tell me the freezing point of water?
    - *32 Degree Celsius*

- How did we end up with frozen ice-cream? The answer lies in the student's understanding of matter.
    - *The ice (solid) absorbs energy causing it to melt going into a liquid.*
- Where does the energy come from to change a liquid to a solid and vise versa?
    - *It comes from all around us, and in this case it came from anything touching the ice during the process*
- What did the salt do to affect our energy?
    - *The salt stops the melting process and lowers the freezing point of the ice, making it colder! This allows the milk to freeze why you were shaking the bag, so by adding the salt we lower the freezing point to 20 degrees Celsius! Just cold enough to make ice-cream!*
- Who can tell me what other parts of chemistry are we using? What do people use chemistry for?

Make Your Own Ice-Cream Student Quick Sheet:

<u>Ice-Cream Recipe:</u>

- Small zip-lock zipper style bag
- Gallon zip-lock zipper style bag
- ½ cup milk
- 1 tablespoon sugar
- ½ teaspoon vanilla extract
- 4 tablespoons of rock salt
- 2+ cups ice cubes
- Hand Towel

<u>After Adding Materials:</u>

1. Shake your bag, with all of the contents, for 8-10 minutes! (Or until it feels like ice cream!
2. Enjoy!

Back-up Units: Materials List

Spacecraft on Mars

Materials:

- 2 worksheets
- 1 Styrofoam cup
- 3 Beakers or baby food jars
- 3 Soil samples (one in each jar)

(*Note*: this is a list of materials per group)

Make Your Own Watercraft

Materials:

- Container filled with water
- 36 inches (1 yard) of transparent tape
- Paper cups (8-ounce or larger)
- 10-to 12-inch strip of plastic wrap
- 10 straws
- Towels (paper or cloth)
- Notebook/ paper and pen/pencil to sketch design
- 25 pennies
- A yardstick (or 3 rulers)

(*Note*: this is a list of materials per group)

Lesson 1: Spacecraft on Mars

(Engineering and Life Science)

Group Size: 2 per group (3 groups)
Time: 1.5 Hour

Introduction:

Engineers design inventions and transportation devices that can explore environments that are unsafe for people like us! *Who can name some of these places?!* One of the most talked about environments like this is outer space! Engineers build robots that are made to look for signs of life (water?) on Mars. They designed rovers that come with many scientific instruments to investigate specific rock and soil targets. For example, these devices have microscopes that take pictures to show really up-close images of rocks, and even come with a tool that tests the rock and soil surfaces.

Explain to the students that today is (**state the current month and day**), 2032, and they have just successfully landed on Mars. Also, they are currently at the Mars Science and Engineering Research Station. *Ask the class if they are tired after their long journey?*

Tell the students they are not the first on this planet, and other scientists are trying to figure out the old question: "Is there life on Mars?" Explain that it is their responsibility to analyze the three soil samples that were collected by the previous manned mission to Mars and left at the Mars Space Station for them to test. By the end of the lesson, they should be able to tell you about life on Mars, and the contents of their soil!

Opening Discussion:

Before the children begin, they must be able to discuss what classifies something as 'living'.

- What are some things that might be found on Mars that would indicate the existence of life? *[Possible answers: water, fossils, vegetation or other life itself]*
- Can you find these sorts of characteristics by testing soil samples? *[Answer: Yes]*.
- Why are there so many different types of soil and why might some have evidence of life while others do not?
    - *[Possible answers: the existence of life may depend on – nutrient content of soil (can they eat in it), what the soil feels like (can they move through it), water content of the soil (can they get water from it), etc.]*

Show the students the examples of living and nonliving things that you have collected and ask students:

- "What characteristics make an individual item alive or not alive?"
    - *[Answers: growth; reproduction, replication or cell division; independent movement; evidence of metabolic processes (respiration, gas or solid material exchange); response to stimuli.]*
- List the answers on the board as student's answer, and pass out the *Are We Alone?* Worksheet
- No idea is too silly, and each student will have the chance to fill out the table on their worksheet before the activity begins
- Have the students state their hypothesis about what they think will happen

SAFETY:

- DO NOT RUB YOUR EYES AFTER TOUCHING SAMPLES
- DO NOT TASTE ANY OF THE SAMPLES

Materials (per group):

- 2 worksheets
- 1 Styrofoam cup
- 3 Beakers or baby food jars
- 3 Soil samples (one in each jar)

Procedure:

1. Pass out the worksheets
2. Fill out the "Criteria for Life" on the *Are We Alone?* Worksheet
    a. Fill out the characteristics on the left, and describe the function on the right
3. Distribute the samples (A, B, & C) to the groups
4. Each team should make a hypothesis about their soil samples and write it on their worksheet
5. Observe the samples, touch and smell them, but DO NOT TASTE! Record observations on Question 1
6. Each group will get a Styrofoam cup of hot water, carefully pour the water over **SAMPLE A** until the sample is covered with water
7. Carefully pour water over **SAMPLE B** until the sample is covered with water
8. Carefully pour water over **SAMPLE C** until the sample is covered with water
9. WAIT FOR 5 MINUTES. Now, observe the samples again and record in question 2
10. Analyze your findings and based on observations conclude if there is any evidence of life (Why is it alive?)
11. Complete questions 3 and 4 and discuss the rest as a class

Closing Discussion:

- You can have the students complete the *Are We Alone*? Worksheet
- Students can present findings in a discussion to their peer.
    - Talk about their trip to mars, what they found, and is there life on Mars?
- Ask the following questions and **write on the board**:
    - Name a living thing that grows?
        - *Plants, animals*
    - Name a living thing that reproduces, replicates, or divides itself?
        - *Bacteria, single-celled organisms, plants, animals*
    - Name a living thing that moves independently
        - *Any animal*
    - Name a living thing that produces gases and performs respiration
        - *Any bacteria, plant, and animal*
    - Name a living thing that responds to a stimulus for protection
        - *Any plant, animal, etc.*

Objectives/Outcomes:

1. Students are able to identify characteristics of a living thing
2. Children are able to explain why some living organisms survive better than other (dependent upon setting)
3. Children systematically investigate and analyze soil samples
4. Students are able to record their observations and conclude that life on Mars exists, based on the results of their soil samples (construct an argument)
5. Students are able to explain why engineers and scientists are interested in finding signs of life within soil samples

Common Core:

- Able to use data from a random sample to draw a hypothesis about an unknown population of interest. Students are able to generate multiple samples of the same size to gauge any variation in estimates or predictions. Gauge how far off the estimate or prediction may be (Grade 7)
- Construct an argument with evidence that in a particular habitat some organism can survive well, some survive less well, and some cannot survive at all. (Grade 3-6)
- Make observations and measurements to identify materials based on their properties (Grade 5-6)

Next Generation Science Standards:

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2- 1)
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS4-4),(MS-LS4-5),(MS-LS4-6)
- Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena. (MS-LS4-4)

Inspired by: eGFI and NASA's Searching for Life on Mars and Destination Mars. (http://teachers.egfi-k12.org/are-we-alone/)

Space Unit Teacher Worksheet

Introduction:

Tell the students they are not the first on this planet, and other scientists are trying to figure out the age old question: "Is there life on Mars?" Explain that it is their responsibility to analyze the three soil samples that were collected by the previous manned mission to Mars and left at the Mars Space Station for them to test. By the end of the lesson, they should be able to tell you about life on Mars. *Ask the class if they are tired after their long journey?*

Opening Discussion:

Before the children begin, they must be able to discuss what classifies something as 'living'.

- What are some things that might be found on Mars that would indicate the existence of life? *[Possible answers: water, fossils, vegetation or other life itself]*
- Can you find these sorts of characteristics by testing soil samples? *[Answer: Yes]*.
- Why are there so many different types of soil and why might some have evidence of life while others do not?
    - *[Possible answers: the existence of life may depend on – nutrient content of soil (can they eat in it), what the soil feels like (can they move through it), water content of the soil (can they get water from it), etc.]*

Show the students the examples of living and nonliving things that you have collected and ask students:

- "What characteristics make an individual item alive or not alive?"
    - *[Answers: growth; reproduction, replication or cell division; independent movement; evidence of metabolic processes (respiration, gas or solid material exchange); response to stimuli.]*
- List the answers on the board as student's answer, and pass out the *Are We Alone?* Worksheet
- No idea is too silly, and each student will have the chance to fill out the table on their worksheet before the activity begins
- Have the students state their hypothesis about what they think will happen

Materials (per group):

- 2 worksheets
- 1 Styrofoam cup
- 3 Beakers or baby food jars
- 3 Soil samples (one in each jar)

For the Teacher (Set-up):

- Create the soil samples for the students before the session begins
    - Soil Sample A: (**Physical change of sugar dissolving)**
        - 1 Teaspoon (5ml) of sugar mixed into less than ¼ cup (50ml) of sand or sandy soil

Soil Sample B: **(Seltzer contains a non-living chemical reaction)**

- 1 Teaspoon (5ml) of sugar and 1 Teaspoon (5ml) of active dry year mixed into less than ¼ cup (50 ml) of sand or sandy soil.
    - Soil Sample C: (**Yeast contains a living chemical reaction—long term)**
        - 1 Teaspoon (5ml) of sugar and 1 crushed Alka-Seltzer tablet mixed in with a little less than ¼ cup (50 ml) of sand or sandy soil
- Class will share hot tap water (**Not too hot---like bath water)**

- Have laid out 10 examples of living and non-living organisms (5 living, 5 non-living). This will start the discussion once you go through the lesson. (Examples: pencil, book, rock, plant, apple, grasshopper or other insect, etc.)

<u>Closing Discussion:</u>

- You can have the students complete the *Are We Alone*? Worksheet
- Students can present findings in a discussion to their peer.
    - Talk about their trip to mars, what they found, and is there life on Mars?
- Ask the following questions and **write on the board**:
    - Name a living thing that grows?
        - *Plants, animals*
    - Name a living thing that reproduces, replicates, or divides itself?
        - *Bacteria, single-celled organisms, plants, animals*
    - Name a living thing that moves independently
        - *Any animal*
    - Name a living thing that produces gases and performs respiration
        - *Any bacteria, plant, and animal*
    - Name a living thing that responds to a stimulus for protection
        - *Any plant, animal, etc.*

Student Quick Sheet to Spacecraft on Mars

Criteria for Life Table

FUNCTION:	DESCRIPTION OF FUNCTION:

Hypothesis for Experiment: ____
____

Before: Before you begin the experiment, write down your observations of your samples.

Sample A: ____
____

Sample B: ____
____

Sample C: ____
____

After: After you finish adding hot water to your samples, take note of your observations.

Sample A: ____
____

Sample B: ____
____

Sample C: ____
____

Sample	Contains Life	
	Yes?	No?
Mars Sample A		
Mars Sample B		
Mars Sample C		

Inspired by: eGFI and NASA's Searching for Life on Mars and Destination Mars.
(http://teachers.egfi-k12.org/are-we-alone/)

Lesson 2: Make Your Own Watercraft

(Engineering, Buoyancy, Displacement)

The duration of the lesson: 30 to 45 minutes
Group Size: 2-3 people per group

Introduction:

In this activity, students will learn about the Engineering Design Process when building a boat, in teams, out of straws and plastic wrap that can hold 25 pennies for at least 10 seconds before sinking. Also, students will learn about the physical principles of buoyancy and displacement.

You are attending a birthday party located in a house across Indian Lake, and you are in charge of bringing all the party supplies. The only way you can get across the lake is by a boat. You must build a boat that is able to carry all the supplies across the lake without sinking, or else the birthday party will be canceled. How are you going to build the boat? How will you make the boat strong enough to carry all the supplies?

Opening Discussion Points:

1. Introduce the challenge by telling the students that they will work with a partner to design and build a boat with materials such as straws, tape, cups, and plastic wrap that will be able to withhold 25 pennies, and can last a duration of 10 seconds without sinking. The Engineering Design Process will be used by the students in order to solve this problem and should be completed with limited time and materials.
2. Give the students some information as to why things float to help them understand the objective of this challenge. For example, ask them: *If you had a large and small empty soda bottle, both with their caps on, which bottle would be harder to keep down if you pushed them underwater?* (Answer: the big bottle)
3. Why? (As you are pushing the bottles down into the water, they will push water out of the way. This is called "displacement." The water that is displaced, pushes back on the bottles with an upward force. This upward force is known as "buoyancy." The more water that is displaced, the bigger the upward push of the water on the bottle. The bigger the bottle will displace more water than the smaller bottle, and thus, there is more force pushing it back up. The bigger bottle will have more buoyancy. The more buoyancy an object has, the higher it floats.)
4. Ask the students how they can design a boat, with the given material, that will displace a large amount of water or will be buoyant.
5. Ask the students to brainstorm and imagine possible ideas on how they will build their boats.
    a. What are the best materials to use when making a boat that is able to support a large load without it sinking?
    b. Should the boat be a flat platform such as a raft, or should it be an open boat?
    c. How big should your boat be in order for it to hold 25 pennies?
6. Allow the students to plan which type of boat they will create and build. Ask the students to fold a piece of paper in half lengthwise and again in half widthwise, creating four rectangular divisions on the paper.

7. Tell the students to draw four different types of boats, one in each rectangle, and then decide on which boat will work best based on the designs.
8. To create their design, students will acquire material from the materials table and will return to their workspace.
9. To test their designs, have the students place their boats in the water, and then add one penny at a time until it sinks or reaches 25 pennies.

<u>Materials:</u>
*****Per team

- Container filled with water
- 36 inches (1 yard) of transparent tape
- Paper cups (8-ounce or larger)
- 10-to 12-inch strip of plastic wrap
- 10 straws
- Towels (paper or cloth)
- Notebook/ paper and pen/pencil to sketch design
- 25 pennies
- A yardstick (or 3 rulers)

<u>Procedure for the Teacher:</u>
Preparation:

- To set up the testing stations, follow the procedure below
- To avoid water spills, cover the surface on which the water-filled container will rest with either plastic wrap, recycled newspaper, or vinyl tablecloth.
- To avoid water spills, place the testing stations on a stable table or on the floor. Fill the containers about halfway (or less) with water. (Note: Do not fill the container more than halfway)
- Place the pennies in a cup near each of the testing stations.

Set up materials table:
**to manage traffic, it is preferred that the materials table is set up way from the testing stations*

- Use a yardstick (or tape down three rulers end to end) as a general measuring guide when dispensing tape and plastic wrap.
- The plastic wrap should be distributed upon request, as it sticks together and is difficult to handle. To limit the amount of plastic wrap that the teams can use, tear off approximately a 10-12 inch long strip for each group (the length doesn't have to be exact).
- The tape should also be distributed upon request. Tear off approximately 36in for each group (again, length doesn't have to be exact).

<u>Conclusion/Closing discussion points:</u>

1. Which boat design worked the best? Why?
2. How can you improve your boat to hold 50 pennies instead of 10?
3. What materials (that were not provided), can help make your boat stronger?

Objectives/Outcomes:

1. Identify how stability and buoyancy are related, and the tradeoffs between them
2. Understand the physical forces that allow objects to sink or float
3. Understand the engineering design process
4. Develop teamwork skills

Common Core State Mathematics Standards:

- Recognize volume as an attribute of 3-dimensional space and understand volume measurement concepts. (Grade 5)
- Solve mathematical problems that can apply to the real world. These problems involve area, volume, and surface area of 2- and 3-dimensional objects. (Grade 7)

Next Generation Science Standards:

- Engineering design: Analyze data from tests to determine the similarities and differences among a few solutions to recognize the best characteristics of each that can be combined into a new solution to better meet the criteria. Ultimately, this will lead to successful results. (MS-PS3-3)

Activity Extension: (~25 minutes)
Using half of the materials, build a boat that can also hold 25 pennies for a duration of 10 seconds.

Inspired by: eGFI Teacher Resources (http://teachers.egfi-k12.org/watercraft/)

Make Your Own Watercraft Teacher Quick Sheet

Intro:

In this activity students will be building a boat, in teams, out of straws and plastic wrap that can hold 25 pennies for at least 10 seconds before sinking. They will learn about the physical principles of buoyancy and displacement.

You are attending a birthday party located in a house across Indian Lake, and you are in charge of bringing all the party supplies. The only way you can get across the lake is by a boat. You must build a boat that is able to carry all the supplies across the lake without sinking, or else the birthday party will be canceled. How are you going to build the boat? How will you make the boat strong enough to carry all the supplies?

Materials:

*****Per team

- Container filled with water
- 36 inches (1 yard) of transparent tape
- Paper cups (8-ounce or larger)
- 10-to 12-inch strip of plastic wrap
- 10 straws
- Towels (paper or cloth)
- Notebook/ paper and pen/pencil to sketch design
- 25 pennies
- A yardstick (or 3 rulers)

Procedure:

Preparation:

- To set up the testing stations, follow the procedure below
- To avoid water spills, cover the surface on which the water-filled container will rest with either plastic wrap, recycled newspaper, or vinyl tablecloth.
- To avoid water spills, place the testing stations on a stable table or on the floor. Fill the containers about halfway (or less) with water. (Note: Do not fill the container more than halfway)
- Place the pennies in a cup near each of the testing stations.

Set up materials table:

**to manage traffic, it is preferred that the materials table is set up way from the testing stations*

- Use a yardstick (or tape down three rulers end to end) as a general measuring guide when dispensing tape and plastic wrap.
- The plastic wrap should be distributed upon request, as it sticks together and is difficult to handle. To limit the amount of plastic wrap that the teams can use, tear off approximately a 10-12 in long strip for each group (the length doesn't have to be exact).
- The tape should also be distributed upon request. Tear off approximately 36in for each group (again, length doesn't have to be exact).

Opening Discussion Points:

1. Introduce the challenge by telling the students that they will work with a partner to design and build a boat with materials such as straws, tape, cups, and plastic wrap that will be able to withhold 25 pennies, and can last a duration of 10 seconds without sinking. The Engineering

Design Process will be used by the students in order to solve this problem and should be completed with limited time and materials.

2. Give the students some information as to why things float to help them understand the objective of this challenge. For example, ask them: *If you had a large and small empty soda bottle, both with their caps on, which bottle would be harder to keep down if you pushed them underwater?*
    a. *(Answer: the big bottle)*
3. Why? (As you are pushing the bottles down into the water, they will push water out of the way. This is called "displacement." The water that is displaced, pushes back on the bottles with an upward force. This upward force is known as "buoyancy." The more water that is displaced, the bigger the upward push of the water on the bottle. The bigger the bottle will displace more water than the smaller bottle, and thus, there is more force pushing it back up. The bigger bottle will have more buoyancy. The more buoyancy an object has, the higher it floats.)
4. Ask the students how they can design a boat, with the given material, that will displace a large amount of water or will be buoyant.
5. Ask the students to brainstorm and imagine possible ideas on how they will build their boats.
    a. What are the best materials to use when making a boat that is able to support a large load without sinking?
    b. Should the boat be a flat platform such as a raft, or should it be an open boat?
    c. How big should your boat be in order for it to hold 25 pennies?
6. Allow the students to plan which type of boat they will create and build. Ask the students to fold a piece of paper in half lengthwise and again in half widthwise, creating four rectangular divisions on the paper.
7. Tell the students to draw four different types of boats, one in each rectangle, and then decide on which boat will work best based on the designs.
8. To create their design, students will acquire material from the materials table and will return to their workspace.
9. To test their designs, have the students place their boats in the water, and then add one penny at a time until it sinks or reaches 25 pennies.

<u>Closer/Assessment:</u>

1. Which boat design worked the best? Why?
2. How can you improve your boat to hold 50 pennies instead of 10?
3. What materials (that were not provided), can help make your boat stronger?

<u>Activity Extension: </u>(~25 minutes)
Using half of the materials, build a boat that can also hold 25 pennies for a duration of 10 seconds.

Make Your Own Watercraft Student Quick Sheet

Materials:
*****Per team
- Container filled with water
- 36 inches (1 yard) of transparent tape
- Paper cups (8-ounce or larger)
- 10-to 12-inch strip of plastic wrap
- 10 straws
- Towels (paper or cloth)
- Notebook/ paper and pen/pencil to sketch design
- 25 pennies
- A yardstick (or 3 rulers)

Appendix I: Additional resources

Within the Appendix are three additional categories of resources. Included are possible grant funding opportunities, tentative field trip ideas/contacts, and any additional contact information necessary.

Possible Grant Funding:

1. DonorsChoose.org
    - Teachers may submit project proposals for materials or experiences (field trips?) – donors supply the funds electronically
2. Captain Planet Foundation Grants ($250-$2500)
    - Applicable to STEM inquiry-based projects that use innovation, biomimicry/nature-based design, or new uses for technology to address environmental problems in *your* community.
3. Nickelodeon Big Help Grant Program
    - Allotted to schools and community organizations enabling kids towards acts of help-- this could be: environment help, leading active and healthy lives, or for improving educational experiences.
4. NASA Opportunities for Educators
    - All grade levels (applications and information on their website)
5. The STEM Pipeline Fund
    - To establish regional STEM networks, promote public awareness, and support nationwide STEM education and workforce development.
    - These grants support plans to expand STEM education with varied activities including hands-on student projects, after school programs, teacher professional development, and parent/student career awareness.
6. Westinghouse Community Giving Grant
    - Awards grant money to community organizations and awards middle and high school students for creative STEM projects. Grants range from $250- $5000 and are awarded on a quarterly basis to non-profit organizations and schools. They also offer K-12 curriculum materials related towards energy and nuclear energy.
7. H.b. Fuller Foundation
    - The efforts are focus in STEM education and leadership development for youth. STEM grants support initiatives in the areas of science, technology, engineering, and mathematics. Grants support programs that help young people become successful, productive, adults.
8. Saxena Family Foundation

- The foundation focuses on advancing inventive and effective ways to promote STEM (science, technology, engineering, and mathematics) education in the United States. Grant making is focused on improving the quality of life of women, children, and senior citizen. Priority is given to empowerment programs that address economic, educational, and political empowerment of women.

Possible Field Trip Ideas:

- Worcester's Ecotarium
  - An afternoon is spent at the Ecotarium. The trip would include various discussion topics centered around exhibits at the organization, and students would be given a chance to reflect on their experience.
    - Call: 508.929.2703 or email reservations@ecotarium.org (link sends e-mail).

- Trip to Worcester Think Tank Maker's Space
  - This is associated with Technocopia due to their recent move. This trip would provide students with the availability to experience first hand the environment of a 'Maker's Space' and the components involved.
    - Contact Information: Lauren Monroe- Co Founder of Worcester Think Tank (lmonroe@worcesterthinktank.com)

- University of Massachusetts Medical School
  - A possible Saturday trip could be arranged to visit the UMASS Medical School, and students would be provided with a tour of the school's facilities and its relation to the STEM disciplines. This would have a greater focus in the biomedical and health service fields.
    - Contact Information: Terence Flotte - Dean of UMASS Medical School (terry.flotte@umassmed.edu)

- Worcester Polytechnic Institute
  - A possible Saturday trip could be arranged to visit one of the labs or facilities at WPI in Worcester. This would allow students to not only visit one of the numerous colleges in the city, but also experience facets of the STEM disciplines more focused in engineering and technology.
    - Contact Information: Martha Cyr- Director of the STEM Outreach Program (mcyr@wpi.edu)

- Bancroft School Robotics Team, Boys & Girls of Fitchburg and Leominster Robotics Competitions
  - All of the previously mentioned schools and organizations offer and host robotics competitions for their students. These competitions are often held on weekends locally within Central Massachusetts. It would also be possible for such robotics teams to make a visit to the gym at the BGCW to exhibit their work.
    - Contact Information:

- Elisa Heinricher- Robotics Coach at Bancroft School (eheinricher@bancroftschool.org)
- Donata Martin- Executive Director of BGCFL (dmartin@bgcfl.org)

Resource Contacts:

- Martha Cyr- Director of the STEM Outreach Program at WPI (mcyr@wpi.edu)
- Elisa Heinricher- VEX Robotics Coach at Bancroft School (eheinricher@bancroftschool.org)
- Donata Martin- Executive Director of BGCFL (dmartin@bgcfl.org)
- Tricia Desmarais- Local Director of Camp Invention in Millbury, MA (td@wpi.edu)
- Dr. Deborah Harmon Hines- Vice Provost of School Services at UMMS (Deborah-Harmon.Hines@umassmed.edu) and Mr. Robert Layne- Director of Outreach Programs for the Worcester Pipeline Collaborative (Robert.Layne@umassmed.edu)

Appendix J: STEM Professionals Portfolio

The following professionals were/are active members in one of the various STEM (Science, Technology, Engineering, or Mathematics) professions. Many of the men and women listed below are in one way or another associated to the Boys & Girls Club of America, the city of Worcester, the state of Massachusetts, or other personal/academic backgrounds similar to those of BGCW members. These character sheets may be separate, and distributed among students after week three of the program (mid-point) as an out of program activity. The sheets could be given to students who have shown interest in one of these professional's specialties in the STEM field--this will add to the exposure and introduce students to successful members of disciplines they have interest in.

Have students research their character further and return to the following class with information on their STEM professional. Build these people into your conversations and discussions with the students.

Loring Coes (1812-1906)

Engineer and inventor

Mr. Loring Coes was born way back in 1812! And he was born right here in Worcester, Massachusetts. He grew up with his brothers working for Kimball and Fuller, a company that made large machines for the wool industry. When he was 24, his family bought the business, but only three years later the building burned down. His family took all of the money they had and moved out of Worcester. It was when they moved that Mr. Coes came up with his invention of the Monkey Wrench! This was the first wrench ever invented that could be adjusted and used with just one hand! He and his brothers made a lot of money from all of the patents on their inventions, and Loring Coes was able to move back to Worcester.

Worcester is known for being an industrial city where many inventors, engineers, and machine workers lived. Without the help of people like Mr. Coes, the industrial revolution would not be the same. Engineers and inventors are creative professionals that are considered part of the STEM (Science, Technology, Engineering, and Math) disciplines. Are there others like Mr. Coes from Worcester?

http://www.davistownmuseum.org/bioCoes.htm

Greg Nelson, Sr. (1949-Present)

Club Director, Orthopedics, Inventor, Business Man

Mr. Greg Nelson is a member of the Boys & Girls Club just like you! He was a member of the Carlsbad, California Boys & Girls Club in the 1960's. Greg and his brother spent a lot of their time at the Club, and spent most of their time in the leadership programs for swim and sports. Then, in 1977 he became the Executive Director of the Club! However, it was after his time working with the Club that he became a professional in the STEM field! In 1987 he founded DonJoy Inc., which is a company that makes orthopedic devices. If you don't know what these are, an example would be the sports/rehab devices that people wear when they have injured themselves and need some support. He went on to found BREG, another orthopedic developer, and both business were extremely successful! Mr. Nelson is currently the CEO of United Orthopedic Group, a major organization that oversees other orthopedic businesses! He has devoted his work to helping people, and has been an active member in the design process of these amazing inventions!

Mr. Nelson is an alumnus from BGCA, can you find other members of the Boys & Girls Club who have been active in the STEM fields like Greg?

http://www.carlsbadmagazine.com/Stories/nelson.html

Elbridge Boyden (1810-1898)

Architect

Mr. Elbridge Boyden is an architect that lived right here in Worcester, Massachusetts! Growing up, Elbridge studied and trained to be a carpenter and architect. His first job once he moved to Worcester was designing an addition for the Worcester State Lunatic Asylum (bet you didn't know we used to have one of those!) People began to hire him for more jobs, and he started his business with a friend called *Boyden & Ball.* During his time in that business, he built and designed so many famous buildings around Worcester. You would best know him as the man who design and help build Mechanics Hall in Worcester! He designed that building back in 1855! He also worked on East Worcester Street School and Cambridge Street School! He is so well known around the city of Worcester for all of the amazing architectural designs that you can still see today driving around Worcester!

Can you research more places that Mr. Elbridge Boyden built? Are there other famous architects from Worcester?

http://blogs.umass.edu/bikehara/2014/03/27/architect-elbridge-boydens-legacy/

Robert Goddard (1882-1945)

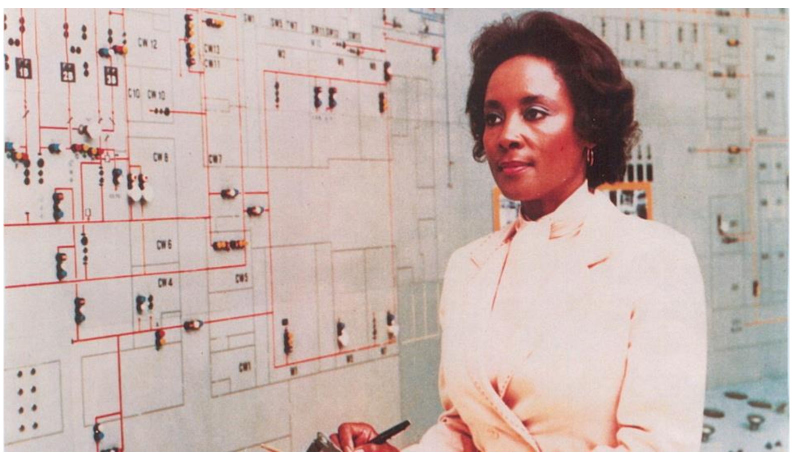
Inventor, Engineer, Theorist, Professor, and Physicist

Mr. Robert Goddard was born and raised in Worcester, Massachusetts back in 1882! Growing up, Robert was extremely interest in the sciences, specifically engineering and technology. He first began learning of electricity, and then moved on to mixing chemicals and causing reactions and explosions in his own house! His dad wanted to continue his interest in science and began bringing home telescopes and microscopes for Robert to learn about. Mr. Goddard then began attempting inventions like metal and hydrogen balloons. It wasn't until he read the book *The War of the Worlds* that Robert became extremely interested in space and aerodynamics. After graduating from South high school here in Worcester, he went on to college at Worcester Polytechnic Institute (WPI) where he studied physics.

Now, Robert Goddard is known as the father of modern rocketry. He is credited with creating, designing, and building the first liquid-fueled rocket in the world. In 1926 he successfully launched that rocket, known as "Nell", right over in Auburn, MA. He started of what we now know as the "The Space Race" because of his complex designs in space-travelling rockets! However, at the time no one really knew who Robert was because they did not believe in his works in space travel and often criticized his ideas. Years later he is recognized for his rockets as well as his scientific studies and designs behind the models. Through his numerous space rocket trials (35 tries!), Robert Goddard made his way in the scientific world by bringing attention to modern rocketry!

http://www.nasa.gov/centers/goddard/about/history/dr_goddard.html

Annie Easley (1933-2011)



Computer Scientist, Mathematician, and Rocket Scientist

Ms. Annie Easley was born in Alabama in 1933! Although she isn't very well known, she has dedicated her work to with the Aeronautics Space Administration in Ohio since 1955. However, it was difficult in the 1950's, before the Civil Rights Movement, for an African American, let alone a woman, get an education. It wasn't until 1954 that it became unconstitutional (illegal!) to segregate public schools. Her mother pushed her throughout middle school, and told her if she got through high school she could be anything that she wanted to be, and was always inspiring to Annie! However, she was unable to get much further than high school for the time being. Therefore, it wasn't until her employers at her company helped send her back to school, and in 1977 she got her Bachelor's degree of Science in Mathematics from the University of Cleveland, Ohio. As part of her schooling, Ms. Easley worked closely with NASA in specific courses they offered. She created and developed a computer coding system that is still being used to determine any solar, wind, and energy in any projects NASA may run. NASA has used her coding to determine the average life of storage batteries in electric vehicles.

They have also used her knowledge and development of computer applications to establish and identify systems of energy conversion that may act as ways to improve available technology. In her work with NASA Centaur project, Ms. Easley's ideas in the technical foundations helped numerous space shuttle launches, and connection to military satellites. Her most memorable work contributed to the 1997 flight of the Cassini probe, one of the first to travel to Saturn.

It was through her hard work and determination that Ms. Easley was able to be one of the first African American women to work alongside NASA. Without her perseverance in so many different STEM fields, we would not have her ideas and contributions she has made to the advancements of the scientific fields.

https://webfiles.uci.edu/mcbrown/display/easley.html

Dr. Aprille Ericsson-Jackson (1963-Present)

Mechanical Engineer, Aerospace Engineer

Dr. Aprille Ericsson-Jackson was born and raised in the Roosevelt projects in Brooklyn, NY. During school, she quickly learned that she got extremely good grades in her science and math classes. Then, even though she knew she was the only African American student to be enrolled, she started taking classes in the Special Progress Program. She ended middle school with high honors, but she wasn't just a science girl! Aprille was part of her school's band, the girl's basketball team, and the science and honors clubs--she really did it all! When she turned 15, she moved to live with her grandparents, who live right near Worcester in Cambridge, MA, and this is where she went to high school! She continued playing basketball and softball, and even volunteered to be the leader in the P.E. program! She's still playing sports to this day! The biggest success Aprille has had was attending college at MIT (Massachusetts Institute of Technology), where she got her Bachelor of Science in Aeronautical/Astronautical Engineering. She worked on a lot of projects that were focused on space flight, which led her to apply to NASA's astronaut program! However, because she played so many sports, she required knee surgery and couldn't become an astronaut. This didn't slow her down though. Aprille went back to school at Howard University in Washington, DC, where she was the first African American woman to graduate with a Master's Degree and Ph.D. in Mechanical Engineering (focused in Aerospace). After all of that hard work, Dr. Aprille Jackson got exactly what she wanted for a career! She currently works at the NASA Goddard Space Flight Center (GSFC) as an aerospace engineer. She works in the guidance, navigation and control section, but her most important work is spent getting girls interested in the STEM fields. She says, "I feel it is important to create an early mathematical and/or scientific interest in young people and maintain it throughout their later years...”

Do your best to go out and find more information on Dr. Aprille Jackson, or see if you can find any women like her in your research!

http://quest.arc.nasa.gov/space/frontiers/ericsson.html

Dr. Aletha Maybank (1974-Present)

Physician

Dr. Aletha Maybank was born April 24th, 1974 in Harrisburg, Pennsylvania, but her family is from Antigua. Interested in being a doctor, she went to Johns Hopkins University, got her medical degree from Temple University, and her Master’s degree of Public Health from Columbia University! Now, she is a very highly respected physician. She works in what is called preventive medicine, focusing on the health of her community’s population! She also works in nutrition and fitness, maternal and child health, cancer research, and HIV/AIDs research and experimentation. Dr. Maybank wants to use her degrees to make a difference in health care nationally and internationally; therefore, instead of only practicing in a hospital, she has become more of a ‘doctor politician’. Aletha Maybank launched a campaign trying to get TV shows to bring the faces of real life African-American doctors, and had a great idea to do so in the popular children’s animated series, *Doc McStuffins*! This was her hope and way of inspiring young Black girls to pursue medical professions, and other STEM related disciplines.
What more can you find out about Dr. Maybank? She is active in introducing young African American women into the STEM topics. (Psst...She’s a founding board members for a Black Women’s Physicians Society)

http://dralethamaybank.com/

Alexa Canady, M.D. (1950-Present)

Pediatrician, Neurosurgeon

Dr. Alexa Canady was born on November 7th, 1950 in Michigan. Her father was a dentist and her mother was a teacher, so growing up Alexa had a lot of STEM influence. Her interest in science grew a lot more intense after her high school offered some science and math courses at the University of Michigan right down the road. She loved the school so much that she later went on to earn a degree in zoology from there and attended the medical school at the University of Michigan too! Dr. Canady got her first job as a surgeon right down in Connecticut at the Yale-New Haven Hospital! However, she didn't stop here. Alexa Canady wanted to make a difference in the face of medicine, and went on to become the FIRST African American Neurosurgeon, after going to train at the University of Minnesota. So, in 1980, she became the first African-American neurosurgeon and went back to work with her old school in Michigan. She went on to become the Chief of Neurosurgery at the Michigan's Children Hospital until she retired in 2001. However, she didn't want to stop here! Dr. Canady went back to practicing medicine part-time later in her life, and this was because she learned that her new community in Florida did not have a practicing African-American surgeon in pediatrics.

Go out and research more about the difference Dr. Canady made in the STEM field.

https://www.nlm.nih.gov/changingthefaceofmedicine/physicians/biography_53.html